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OCTOBER 1928

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PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

MEETINGS

of the

American Institute of Electrical Engineers

REGIONAL MEETING, Southern District No. 4, Atlanta, Ga., October 29-31, 1928

WINTER CONVENTION, New York, N. Y., January 28-February 1, 1929

REGIONAL MEETING, Middle Eastern District No. 2, Cincinnati, Ohio, March 20-22, 1929

REGIONAL MEETING, South West District No. 7, Dallas, Texas, May 7-9, 1929

SUMMER CONVENTION, Swampscott, Mass., June 24-28, 1929

MEETINGS OF OTHER SOCIETIES

National Safety Council, Hotel Pennsylvania, New York, N. Y., October 2-5, 1928

American Welding Society, Philadelphia, Pa., Oct. 8-13, 1928 (M. M. Kelley, 33 W. 39th St., New York, N. Y.)

National Electric Light Association
Kansas Section, Wichita, Kan., October 18-19, 1928

JOURNAL

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American Institute of Electrical Engineers

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PUBLICATION COMMITTEE

W. H. GORSUCH, *Chairman*, H. P. CHARLESWORTH, F. L. HUTCHINSON, DONALD MCNICOL, E. B. MEYER

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DEVOTED TO THE ADVANCEMENT OF THE THEORY AND PRACTISE OF ELECTRICAL ENGINEERING AND THE ALLIED ARTS AND SCIENCES

The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.

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A MESSAGE FROM THE PRESIDENT

Our Membership

A HEALTHY growth of the Institute with a continued forward march in step with the progress of the electrical industries requires that there be a fairly continuous influx of desirable new members.

If membership in the Institute shall carry with it an indication of merit and a mark of distinction the classes of membership should be carefully guarded.

Here are two fundamentals affecting the well being of the Institute which concern every member.

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The Membership Committee promotes activity leading to membership increase. It is not of the so-called booster committee type. While its principal aim is the adding of members it keeps in mind that only such men are worth having as can appreciate the great advantages of membership once they have been pointed out to them.

This Committee has two main lines for action:

A—To see that men who seem to be of the type to make desirable members are exposed to the influence of the Institute, principally through Section activities;

B—To help make Section activities of the kind that will appeal to such men.

"A" requires personal work, such as visits to prospects and, in some cases, interviews with their chiefs to learn of the desirability of the prospect as a member and to obtain support in interesting him in the worth of the Institute.

For "B" the local Membership Committee representative should preferably be on the Section's program committee.

As a further step it is suggested that where a section is located in one of the larger centers it should have an Engineering Graduates Committee of which the local Membership Committee representative is a member. This committee could obtain the names of former enrolled students who have found employment in its city. By showing an interest in these young graduates their interest in remaining identified with the Institute should readily be obtained.

Surely here is a field for the Membership Committee (and every Institute member should feel himself a part of it) where successful results bring high returns both to the young engineer and to the Institute.

o

Of our present membership of over 18,000 nearly 80 per cent are Associates. If it were a fact that four-fifths of today's American electrical engineers are "qualified to fill a subordinate position in engineering work, or identified in a responsible capacity with an electrical enterprise," but that only one-fifth have reached the higher qualifications for Member or Fellow, then this would indeed be a sad reflection on the progress of our electricals these past decades. Of course, that is not a fact but the true condition should be expressed by transfer to the higher grade of those who qualify. A glance at the Year Book shows them on nearly every page.

Less than 4 per cent are Fellows. That also seems a bit low and the Year Book discloses the names of many Associates and Members who fully qualify for the highest grade.

This suggests a thought on our system of grading and on the desirability of having the applicant state the grade himself. Would it not in general be preferable to have the applicant's sponsors or references state the grade for which they recommend the applicant, setting forth fully their reasons for the recommendation? This is done with success in at least one large engineering society. It would be interesting to hear from our members on this point.

R. F. Schuchardt

Nomination of Officers of the A. I. E. E.

The actions specified in the Institute's Constitution and By-laws relative to the organization of a National Nominating Committee are being taken, and the meeting of the National Nominating Committee for the nomination of officers to be voted upon at the election in the Spring of 1929 will be held between November 15 and December 15. All suggestions for the consideration of the National Nominating Committee must be received by the Secretary of the Committee at Institute Headquarters, New York, not later than November 15.

The sections of the Constitution and By-laws governing these matters are quoted below:

CONSTITUTION

28. There shall be constituted each year a National Nominating Committee consisting of one representative of each geographical district, elected by its Executive Committee, and other members chosen by and from the Board of Directors not exceeding in number the number of geographical districts; all to be selected when and as provided in the By-laws; The National Secretary of the INSTITUTE shall be the secretary of the National Nominating Committee, without voting power.

29. The executive committee of each geographical district shall act as a nominating committee of the candidate for election as vice-president of that district, or for filling a vacancy in such office for an unexpired term, whenever a vacancy occurs.

30. The National Nominating Committee shall receive such suggestions and proposals as any member or group of members may desire to offer, such suggestions being sent to the secretary of the committee.

The National Nominating Committee shall name on or before December 15 of each year, one or more candidates for president, treasurer and the proper number of managers, and shall include in its ticket such candidates for Vice-Presidents as have been named by the nominating committees of the respective geographical districts, if received by the National Nominating Committee when and as provided in the By-laws; otherwise the National Nominating Committee shall nominate one or more candidates for vice-president(s) from the district(s) concerned.

BY-LAWS

SEC. 21. During September of each year, the Secretary of the National Nominating Committee shall notify the chairman of the executive committee of each geographical district that by November 1st of that year the executive committee of each district must select a member of that district to serve as a member of the National Nominating Committee and shall, by November 1st, notify the secretary of the National Nominating Committee of the name of the member selected.

During September of each year, the Secretary of the National Nominating Committee shall notify the chairman of the executive committee of each geographical district in which there is or will be during the year a vacancy in the office of vice-president, that by November 15th of that year a nomination for a vice-president from that district, made by the district executive committee, must be in the hands of the Secretary of the National Nominating Committee.

Between October 1st and November 15th of each year, the Board of Directors shall choose five of its members to serve on the National Nominating Committee and shall notify the secretary of that committee of the names so selected, and shall also notify the five members selected.

The Secretary of the National Nominating Committee shall give the fifteen members so selected not less than ten days' notice of the first meeting of the committee, which shall be held not later than December 15th. At this meeting, the committee shall elect a chairman and shall proceed to make up a ticket of nominees for the offices to be filled at the next election. All suggestions to be considered by the National Nominating Committee must be received by the secretary of the committee by November 15th. The nominations as made by the National Nominating Committee shall be published in the January issue of the A. I. E. E. JOURNAL, or otherwise mailed to the INSTITUTE membership during the month of January.

F. L. HUTCHINSON,
National Secretary

October 1, 1928

Some Leaders of the A. I. E. E.

FRED STANLEY HUNTING, Manager of the Institute 1911-1914 and its vice-president from 1914 to 1916, was born at Templeton, Massachusetts, on the thirtieth of September 1867.

After graduating from the Templeton High School in 1884, he entered upon a course at the Worcester Polytechnic Institute, from which he graduated in 1888 with a degree in Mechanical Engineering. He later obtained his B. S. degree from this same school, ranking second in his department.

Immediately after graduation, he entered the employ of the Fort Wayne Electric Company, where, for the first three years, he was engrossed in experimental testing work and the design of electrical apparatus. He made a special study of the development of transformers and a-c. distribution and performed some unique tests on electrical apparatus. Later he was appointed assistant to M. M. M. Slattery, then chief electrical engineer of the company, and in September 1893, Mr. Hunting became chief construction engineer, directing the installation of many representative plants. Subsequently he was chosen treasurer and sales manager of the company, and ultimately was elected its vice-president and treasurer.

In 1911 he received his appointment as general manager of the Fort Wayne Works of the General Electric Company, and in this capacity he served until 1922, when he joined the Robbins & Meyer Company, of Springfield, Ohio, as its president.

Several large central station switchboards are the products of his ability in electrical design work; for some time was associated with Mr. C. S. Bradley—also a member of the Institute—in his laboratory experimental and development work carried on in New York City.

Mr. Hunting retired from active business a short time ago, and has recently been made a Member for Life of the Institute, which he joined in 1892 as an Associate. He was transferred to the grade of Fellow in 1913. He is a director of the Lincoln National Life Insurance Company, a member of the Commercial and Country Clubs of Springfield, Ohio, and also of the Union Club of Cleveland.

Economies in Central Power Service
as Illustrated by the Duke Power System

BY W. S. LEE[1]
Fellow, A. I. E. E.

Synopsis.—*This paper invites the attention of the engineering profession to the advantages and economies which may be obtained by coordinating both hydro and steam power stations of various kinds, and electric transmission and distribution lines serving a large industrial territory in a unified and centrally controlled system. For illustration, a general description of the generating and distribution system of the Duke Power Company, operating in the Piedmont section of the Carolinas, is given.*

EVERYONE who studies the statistics on electric power output in the United States will be amazed at the rapid growth of the electrical industry during the past decade and how, by the construction of larger and larger commercial electrical central stations and the merging of existing electrical properties, the increasing demand for electricity for lighting, power, and transportation was met.

Through this centralization, it was made possible to give uniform and dependable service to the customer, to maintain the same rates, and even lower them to domestic consumers in the face of increasing costs of labor and materials, to make the investments in properties of such character safe and attractive, to afford the support of an organization highly trained in the efficient planning, constructing, operating and improving of utility systems, to make purchases in large quantities and to aggressively engage in building-up the electric light and power business. Other advantages are the grouping of hydro and steam power stations of various kinds to permit the full and economical utilization of the available natural resources of power.

The large generating plants deliver the electric energy to trunk transmission lines which feed the distributing systems of cities and towns and furnish power to the lines at industrial centers. In addition, interconnections of trunk lines of the transmission systems of large independent power companies operating in adjoining territories provide means for marketing wholesale power blocks from one utility to another, for interchange of power between systems and, in case of emergency, for stand-by service.

Due to their higher plant efficiencies and the lowering of construction costs, the number of large steam electric generating stations is rapidly increasing and water-powers of large size, which were considered uneconomical on account of the inability of marketing such large blocks of power within a reasonable period of time by local utilities, are being developed. Industrial plants abandon operation of their old inefficient power stations, and wasteful generating stations of small suburban electric properties are being shut down. An increasing number of manufacturing plants is being located away from the large centers of population, this trend towards decentralization being made possible by reason of the fact that high-tension transmission lines can be tapped at suitable locations away from metropolitan areas. Old inefficient water-power plants are being overhauled and existing hydro stations utilizing only portion of the available water-power of the stream are being rebuilt and enlarged so as to lower the cost of the electric power generated.

A striking example showing the development of a local concern organized for the sale of electricity generated at a single water-power plant about 23 years ago to one of the largest central stations generating and distributing systems in the world is given by the Duke Power Company operating in the Piedmont section of the Carolinas. This company is now operating a number of hydro and steam electric plants having an aggregate installed capacity of 873,895 kv-a., and the power is fed into a transmission and distribution system consisting of approximately 4000 mi. of circuits, of which about 50 per cent are 100,000-volt steel tower lines. One hundred and sixty thriving industrial communities and many isolated cotton mills and factories are served by these lines, and in 1927 the total power generated and purchased by the Duke Power System amounted to 1,745,776,428 kw-hr. This compares with an average output of 19,000,000 kw-hr. of the old Catawba Station, which was the first plant operated and which was redesigned and reconstructed in 1925.

The generating system of the Duke Power Company may be subdivided into the following groups:

1. Hydro stations which use the fall and run of the river.
2. Hydro stations which use the fall and run of the river plus a small amount of storage taking care of the night and Sunday flow and, perhaps, of minor weekly fluctuations of the flow of the river.
3. Hydro stations which have a large storage capacity behind them and which are used as a valve, or outlet, to supply the deficiency in power of other stations during low-water seasons.
4. Steam plants designed to operate intermittently and during low-water periods, termed "stand-by plants."
5. Steam plants designed to operate twelve months of the year and capable of supplying a constant amount of power, termed "base plants."

Of special interest are the twelve hydro stations

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1. Vice-president and Chief Engineer, Duke Power Co., Charlotte, N. C.

Presented at the Regional Meeting of Southern Dist. No. 4 of the A. I. E. E., Atlanta, Ga., Oct. 29-31, 1928.

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located on the Catawba River the flow of which is almost completely regulated so that all these stations may be classed under Group 3. Beginning with the power plant farthest upstream, the names and installed capacities of these stations are as follows:

Name of hydro station on Catawba River	Rated capacity of station kv-a.
Bridgewater	25,000
Rhodhiss	21,875
Oxford	45,000
Lookout Shoals	23,400
Mountain Island	75,000
Catawba	75,000
Fishing Creek	37,500
Great Falls	30,000
Dearborn	56,250
Rocky Creek	30,000
Cedar Creek	56,250
Wateree	70,000
Total	555,275

The Bridgewater, Rhodhiss, and Oxford Stations, located in the upper region of the Catawba River, and the Catawba Station, located below the junction of the South Fork of the Catawba River, have large storage reservoirs behind them for the retention of the flood-waters and excess flow of the river.

The aggregate installed capacity of the six steam power plants is 244,313 kv-a., of which the Buck Station, using powdered fuel and having a rated capacity of 87,500 kv-a., is to be classed under Group 5. It should be added that the Duke Power Company now has under construction a large powdered fuel steam power station on the Catawba River near the Mountain Island hydro station, where an ample supply of condensing water is available. This station is located closest to the center of gravity of the entire load system and the initial installation will consist of two 60,000-kw. units, whereas the plans call for an ultimate installation of 480,000 kw.

The hydro stations to be classed under Groups 1 and 2 are operated in conjunction with the stand-by steam plants under Group 4, which arrangement will permit the most effective utilization of the stream flow under the conditions. The locations and rated capacities of these stations are as follows:

Name of hydro station	Name of River	Rated capacity of station kv-a.
Gaston Shoals	Broad	12,750
99 Island	Broad	22,500
Tuxedo	Green	6,250
Turner	Green	6,880
Portman Shoals	Seneca	9,500
Gregg Shoals	Savannah	2,250
Lake Lure	Rocky Broad	4,500
Saluda	Saluda	2,600
Idols	Yadkin	1,000
Plants of less than 1000 kv-a. capacity		6,077
Total		74,307

The steam power plants are located at strategical points of the system; combining Groups 4 and 5, they are:

Name of steam station	Rated capacity of station kv-a.
Buck	87,500
Eno	31,250
Greensboro	8,000
Greenville	8,000
Mount Holly	45,500
Tiger	37,500
Stations leased	26,563
Total	244,313

A summary giving the generating capacity of the Duke Power System, arranged by groups, discloses the following interesting facts:

Number of group	Total rated capacity of stations kv-a.	Per cent of total capacity of entire system
Hydro No. 1	7,777	0.89
Hydro No. 2	66,530	7.61
Hydro No. 3	555,275	63.54
Steam No. 4	156,813	17.95
Steam No. 5	87,500	10.01
All groups	873,895	100.00

If the steam power station of 150,000 kv-a. initial capacity now under construction is included, the ratio of steam to total generating capacity of the system will be increased from 27.96 per cent to 38.51 per cent.

To give an outline of the transmission and distribution system of the Duke Power Company, 100,000-volt double-circuit feeder lines from points of concentration of power generation tap the 100,000-volt double-circuit trunk lines running through the load centers of the Piedmont Section of the Carolinas. At these centers, the current is stepped down to 44,000 volts and delivered to the distribution system. The object of using the lower voltage is to reduce the cost of the substations serving the large power customers and public utility branches of the company; and wherever feasible, a generating station is tied-in directly to the 44,000-volt system to avoid double transformation.

At present approximately the following lines are in operation:

Voltage of circuit	Approximate length of circuit miles
100,000	2000
44,000	1900
13,200	100

The standard secondary delivery voltages are 575 and 2300.

Interconnection of the Duke Power Company's trunk lines is made for delivery of large blocks of power to it at the High Rock Station on the Yadkin River of the Tallassee Power Company, and a line is contemplated

for connection with the hydro plant of the Lexington Water Power Company, now under construction on the Saluda River near Columbia, S. C. Interconnections for interchange of power and stand-by service are made with the trunk lines of the South-Eastern Power Company and the Carolina Power & Light Company.

In the process of development of the Duke Power Company effort was made to maintain the entire system in good operating condition and to obtain the best results by making improvements on existing plants wherever necessary, even to the extent of abandoning old plants in the interest of fuller and more efficient utilization of the properties. This latter policy was followed up with the fullest success in the case of the old Catawba Station representing an investment of more than one million dollars.

As already mentioned, this hydro plant containing eight rope-driven generators of a total capacity of 8000 kv-a. was built 23 years ago. The normal head at this station was 23 ft. and the over-all efficiency of the plant was about 70 per cent. The storage capacity of the pond was practically negligible and to obtain the benefit of the night and Sunday flow, the plant had to be operated continuously. Furthermore, the available uniform flow at this station was considerably augmented due to the regulating effect of the large storage reservoirs, since built on the Upper Catawba River. The question therefore arose whether additional machinery should be installed and the old plant overhauled or the dam be raised so that the water would back to the tail-race of the company's Mountain Island Station, 25 mi. further upstream, thus creating another large storage reservoir, and the building of an entirely new power house. By the adoption of this latter scheme, not only a reservoir of approximately ten billion cubic feet available storage capacity was created, making an additional regulated flow available at the existing stations on the lower Catawba River with a combined head of 250 ft., but the installation of the new power station could be increased from 8000 kv-a. of the old station to 75,000 kv-a. due to the higher head of 70 ft. and full utilization of the regulated stream flow.

The map in Fig. 1 shows the outline of the states of North and South Carolina. There is shown by dots, each 10,000 spindles located within these two states. It will readily be noted that the industrial expansion follows the transmission lines of a central system.

Notwithstanding the great industrial development in the Carolinas during the last ten years, the prospects for further growth of the electric light and power business are very bright. The demand for power and light in the home, on the farm and in industries is increasing steadily and new fields are being opened up constantly.

In anticipation of this ever increasing demand for electric energy, the Duke Power Company is going ahead with a definite program of extensions and improvements to its system to meet future service requirements.

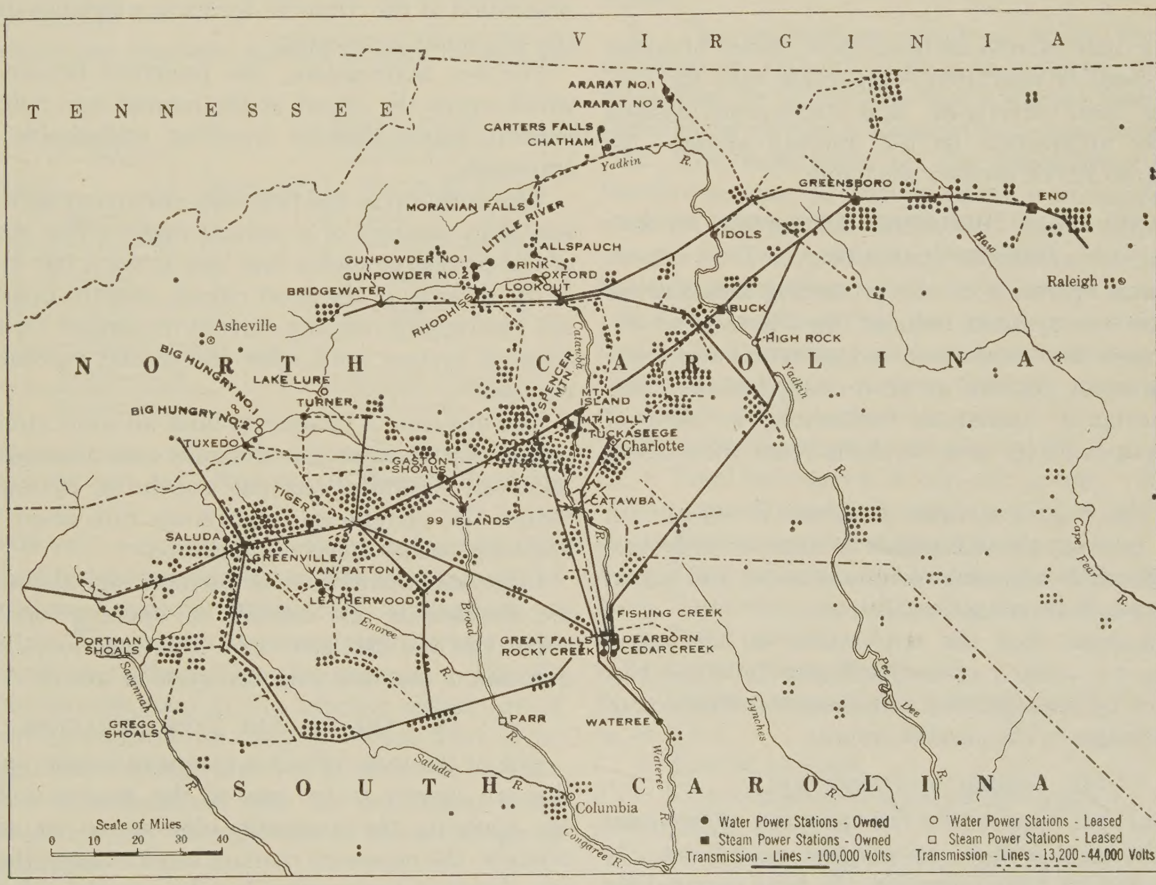


Fig. 1

Abridgment of

High-Speed Circuit Breakers

BY T. W. McNAIRY[1]

Associate, A. I. E. E.

Synopsis.—*High-speed circuit breakers have been successfully applied to d-c. railway systems for a number of years, but designs suitable for application on 12,000-volt single-phase systems have not been available until recently.*

A description of an air circuit breaker design suitable for 12,000-volt applications and having a speed of operation comparable with the d-c. type has been included.

The method of applying the magnetic type of mechanism previously used for d-c. breakers to the a-c. type breaker has been described. The theory of the operation of the saturated transformer type of trip circuit used for this purpose has been given.

Typical oscillograms of short-circuit tests, showing the high speed of operation on a-c. circuits, are included.

The method of obtaining selective operation in connection with railway feeder circuits has also been outlined.

The use of this type of breaker on a 12,000-volt single-phase system makes possible the same degree of protection and selective operation as is now being realized on d-c. systems.

I. Introduction

HIGH-SPEED circuit breakers were first applied on d-c. railway systems for the protection of commutating apparatus against the effects of short circuits or flashover. Later development led to their application to all of the power circuits of this type of system.[2]

Recently, both oil and air break type circuit breakers having a speed of operation comparable with the d-c. type have been developed, and commercial designs suitable for application on a-c. railway systems for voltages up to 12,000 are now available.

II. Advantages of High-Speed Operation on A-c. Railway Circuits

High-speed operation of the protecting breakers for single-phase a-c. systems reduces the effects of short-circuit stresses on transformer and generator windings, and in the same manner as on d-c. applications, limits the burning of insulators, conductors, or parts of motive equipment by arcs resulting from these short circuits.

One of the most important problems in connection with a-c. railway electrifications is that of inductive interference with adjacent communication and signal circuits under short-circuit conditions.

It is expected that the application of high-speed breakers to a-c. railway systems will greatly reduce this interference by reducing to a minimum the duration of induced voltages in the parallel circuits.

III. Speed of Operation

The total time required for the operation of the usual a-c. circuit breaker may be divided as follows: (1) Time required for relay operation; (2) time required for the separation of contacts; and (3) time required for extinguishing the arc.

In some forms of breakers, particularly those made the subject of this paper, the relays have been eliminated, the circuit breaker being operated directly by the short-circuit current.

The speed of the operation of the mechanism is more or less definitely fixed by the mechanics of the device, and separation of the contacts occurs at a definite time after the trip point is exceeded.

For a-c. applications, the preferred breaker is one which opens the circuit at the normal zero point of the current wave, thereby avoiding undesirable voltage transients.

The duration of the first loop of current is frequently less than one-half of a normal cycle. The magnitude of the current of such a first loop is not a fair indication of the severity of the short circuit, and the breaker does not receive full tripping current or current through the blowout system until after the second current loop is reached.

The design of a breaker to limit all short circuits to a single loop of current is difficult, and if successful, the relatively powerful current rupturing system might reduce the current at a dangerous rate when the first loop approaches a cycle in duration.

It appears therefore that the most logical design of an a-c. breaker is one capable of opening heavy short circuits at the first zero after a current loop, having a duration of one-half a normal cycle or longer.

IV. Oil vs. Air Type Breakers

One of the most effective means of rapidly increasing the arc length is by use of the magnetic blowout. By applying the magnetic blowout to an oil circuit breaker, the necessary contact separation at the instant the circuit is interrupted can be greatly reduced, and high-speed operation can be obtained with a mechanism moving at moderate speeds.

Where possible, however, elimination of oil is always desirable; and this is particularly true for railway applications.

The effect of repeated interruptions on oil circuit

1. Control Division Railway Equip. Engg. Dept., General Electric Company, Erie, Pa.

2. A. I. E. E. Trans., Vol. XLV, 1926, p. 962.

Presented at the Summer Convention of the A. I. E. E., Denver, Colo., June 25-29, 1928. Complete copies upon request.

breakers is well known. If a given circuit breaker is called upon to open a circuit repeatedly without attention, the oil deteriorates to such an extent as to endanger the reliability of the breaker. Repeated short circuits are most likely to occur during bad weather conditions, when filtration or changing of the oil is most difficult, particularly in outdoor installations. Assuming, therefore, that it is the equivalent of the oil breaker in all other respects, the air breaker is much to be preferred for this type of service.

During experimental investigations, a-c. air-break breakers have withstood 20 or more maximum short circuits, repeated at two-minute intervals, without requiring attention or without deterioration of the current rupturing ability, and in this respect they are on a par with the d-c. type.

V. Magnetic Operating Mechanism

Practically all d-c. high-speed breakers are of the magnetic tripping type, most designs making use of a flux shifting principle where the flux is shifted from a holding armature to a magnetic by-pass circuit to release the breaker.

The mechanism has been applied to both oil and air

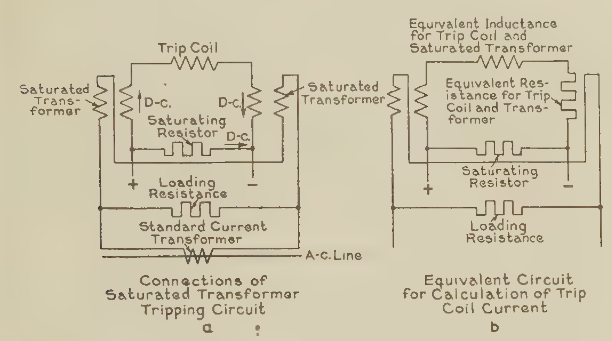


Fig. 3—Connections of the Tripping Circuit for the Magnetic Type of A-c. High-Speed Circuit Breaker

type 12,000-volt a-c. breakers. Some means of providing a unidirectional current in the tripping coil of this type of mechanism is essential for applications on a-c. circuits. The saturated current transformer type of trip circuit was adopted for this purpose. (Fig. 3).

The transformers used in the tripping circuit are of normal current-transformer design. When there is no a-c. through the windings, the flux in the cores of these transformers is maintained near the saturation point by the direct current through one of the windings of each transformer.

The connections are such that when current of given direction is passed through the primary winding of both transformers, such as during the first half-cycle of an a-c. short circuit, it exerts a magnetic motive force to increase the flux in the core of one transformer and decrease the flux of the other transformer, simultaneously.

Since the cores of both transformers are initially saturated in opposite directions, the decreasing flux in one transformer generates a secondary voltage, whereas the transformer in which the flux is increasing generates only a slight secondary voltage because of saturation in the core.

The secondary voltages of the two transformers are connected in opposition around the tripping-coil circuit, and the resultant unbalanced voltage circulates current around the circuit formed by the trip-coil transformers and resistors, as shown by the current curve of Fig. 4B.

No matter what the direction of the primary current, one transformer will be active on the first half cycle, the polarities being such that the current impulse through the trip coil is always in the same direction. The phenomena is transient and the unidirectional current is not maintained under steady state conditions.

This arrangement does not provide a steady overload trip point so that standard types of over-current relays are usually provided for this purpose.

In an endeavor to provide a more complete explanation of the operation of these saturated transformers, the following analysis is offered, with assumptions as stated:

1. The transformer which is active for a given direction of primary current is assumed to hold its ratio from the instant the flux is started down; that is, the exciting current is assumed to be negligible.

2. The inductance of the transformer which is inactive because of saturation has been assumed to be constant above the saturation value. The current through both the primary and secondary windings of the inactive transformer acts to increase the saturation.

3. It is assumed that the transformer which is inactive on the preceding half cycle immediately becomes active as the total current through the windings is reduced to the d-c. saturation value.

The following symbols are employed:

L_1 = Total inductance of trip-coil circuit. (Saturated transformer and tripping coil.)
R_1 = Total resistance of trip-coil circuit.
L_2 = Total inductance of loading circuit Fig. 3.
R_2 = Total resistance of loading circuit Fig. 3.
I = Total current.
i_1 = Current through trip coil.
i_2 = Current through coil loading circuit.
$\omega = 2\,\pi\,f$.
t = Time in seconds.
T = Time constant of main power circuit.
e = 2.718.
γ = Time phase angle of the starting moment.

The equivalent circuit for the period during which a current impulse is passing through the tripping coil is shown on Fig. 3b.

The current through the tripping coil of the circuit breaker is determined by the following equation:

$$i_1 = I_M$$

$$\left[\left(\frac{R_2\,(R_1 + R_2) + \omega^2\,L_2\,(L_1 + L_2)}{(R_1 + R_2)^2 + (L_1 + L_2)^2\,\omega^2} \right) \sin\,(\omega\,t - \gamma) \right.$$

$$+\left(\frac{\omega L_2 (R_1 + R_2) - R_2 \omega (L_1 + L_2)}{(R_1 + R_2) + (L_1 + L_2)^2 \omega^2}\right) \cos(\omega t - \gamma)$$

$$+ \frac{(R_2 T + L_2) \sin \gamma}{T (R_1 + R_2) - (L_1 + L_2)} e^{-\frac{t}{T}} + c\, e^{-\left(\frac{R_1 + R_2}{L_1 + L_2}\right) t}\Bigg]$$

The above relation holds only during the period when one transformer is active and the other inactive.

The breaker is released on the first current impulse, which exceeds the trip point; and the determination of the first tripping impulse is most important in connection with breaker performance.

The current through the trip coil of the circuit breaker

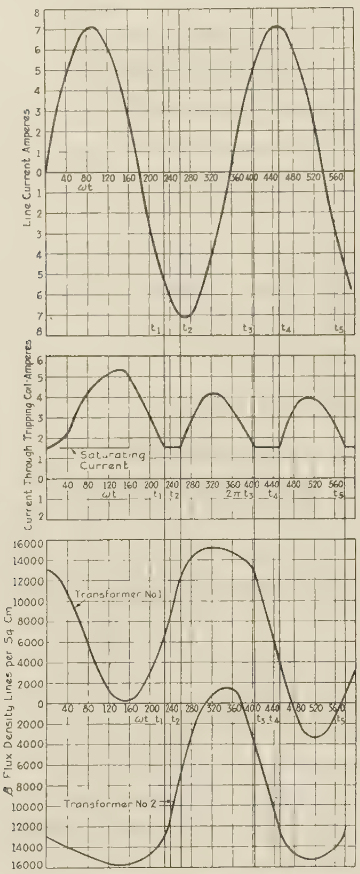


Fig. 4—Calculated Current and Flux Curves for Saturated Tripping Transformers used in Connection with the Magnetic Type of Mechanism of the A-c. High-Speed Circuit Breakers

(Fig. 4) for a symmetrical short circuit has been calculated for a typical case using equation (**6**).

The calculated flux curve is shown by Fig. 4c.

It will be noted that at the time t_1 the current through the windings of the inactive transformer is reduced to the d-c. saturating current value, as the line current increases during the second half cycle, a voltage is induced in the secondary winding of this transformer. From the flux curve Fig. 4c, however, it will be seen that the flux of the previously active transformer has not yet returned to the saturation value, and therefore there is a period from t_1 to t_2 where both transformers are active and present full transformer reactance to the flow of current, and (ignoring the exciting current for the transformers) the total line current flows through resistance R_2.

The flux change in both transformers for the period t_1 to t_2 is therefore determined by the voltage across the loading resistor R_2 Fig. 3A.

$$E = 10^{-8}\, I_M\, R_2\, N\, A \frac{d\,\Phi}{d\,t} = I_M \sin \omega t$$

$$\Phi = \frac{12 \times 10^8}{N\,A} [-\cos \omega t]$$

The corresponding flux curves for the period t_1 to t_2, until the flux transformer No. 1 again reaches the saturation point, is shown on 4c. After the saturation is reached in the case of No. 1 transformer, a second current impulse is passed through the trip-coil circuit by No. 2 transformer, the method of determination being the same as for the first impulse. At the conclusion of the second impulse t_3, the flux of the second transformer is further from the saturation value than was the flux of No. 1 transformer at the end of the first loop, and the line current again passes through R_2 until saturation is reached, the period from t_3 to t_4 being correspondingly greater than the period from t_1 to t_2.

In this manner, the phenomena is repeated, the period in which both transformers are active growing longer with each succeeding half cycle until a stable condition is reached, where the flux is increasing through one transformer and decreasing through the other transformer for the full half cycle. When this occurs, the sustained condition has been reached and no further current impulses are supplied to the trip coil, so long as the line current is not increased. Under steady-state conditions the full line current passes through the resistance R_2.

The trip current supplied by this tripping circuit is approximately proportional to the increase in line current.

After the steady-state condition is reached, should the line current again be increased suddenly, the saturation point on one transformer occurs as soon as the line current exceeds the steady-state value and further current impulses are supplied through the tripping-coil circuit.

VI. Description of the Air-Break Circuit Breaker

Reproductions of photographs of a 12,000-volt, 1500-ampere, single-phase air-break circuit breaker are shown in Figs. 1 and 2 of the complete paper. A drawing of the principal parts of the mechanism is shown in Fig. 5.

This mechanism is inherently trip free in its operation.

The high-voltage circuit through the breaker is very direct, entering on one side through series blowout coils,

one end of which is connected to a stationary contact. The circuit is completed through the moving contact and arm, and another set of series blowout coils from which the connection is made to the second contact mechanism, a duplicate of the first.

When the contacts separate under short-circuit conditions, the arc is drawn on the arcing horns, and detached blowout coils are cut in successively as the arc travels along these horns.

A new feature introduced in this breaker consists of high-resistance arcing horns, made from a special material, and designed to absorb a considerable voltage as the arc is forced along them under the action of the blowout coils. These arcing horns are effective in reducing the energy in the arc stream and in reducing the flame and noise of the breaker when opening under short-circuit conditions.

VII. Current Rupturing Tests on Air Breaker

This breaker has successfully opened a current of 24,000 amperes, r. m. s. at 14,000 volts repeatedly. A series of twenty OCO tests at 12,000 volts, 22,000 amperes, r. m. s. were made at two-minute intervals without examination or attention of any kind to the circuit breaker.

A single contact and arc chute of this type of breaker, equivalent to one-half the standard 12,000-volt breaker, has opened a maximum current of 41,000 amperes r. m. s. at 7000 volts repeatedly, both tests at 14,000 and 7000 volts being the maximum available at the time the tests were conducted.

VIII. Selective Operation of the High-speed A-c. Breaker

Selective operation of high-speed a-c. breakers applied to railway feeders is essential.

The connections shown in Fig. 13 are utilized for obtaining selective operation where the unidirectional-current impulse type of trip is used. Advantage is taken of the unidirectional trip circuit in a differential connection. The tripping circuits of all breakers are connected to a common bus in such a way that the trip current circulating through any trip coil must return through either the trip coils of parallel breakers or the saturating resistor indicated on the diagram. When the current is increased simultaneously through all breakers supplying the feeders in a given direction from the substation, the tripping current for all of these breakers must pass through the saturating resistor shown on the diagram, since equal voltages are generated by the trip circuits of each breaker. The current required for tripping all of the circuit breakers under this condition is much higher than when the current is increased through one breaker only.

If, by a short circuit on one feeder, the current is increased suddenly in one breaker only tripping current is supplied to the breaker in the faulty feeder, this current returning through the coils of the remaining breakers and assisting to hold them closed.

The tripping current for the breaker is considerably less than when all breakers carry current because of the lower impedance of the return circuit for the tripping current.

The operation of the breakers under typical short-circuit conditions with connections as shown in Fig. 13 is as follows:

Feeder Short Circuits. In the event of a short circuit on a feeder between substations, the breaker supplying this feeder carries a current considerably in excess of that of the parallel breakers, since the parallel breakers carry the exchange current between substations only. Tripping current is supplied to the trip coil of this breaker operating it, some of this current returning through the trip coils of the parallel breakers in reverse direction for tripping and assisting in holding them closed.

In the event of a feeder short circuit directly in front of one substation, all of the breakers in the distant substation carry equal currents until after the breaker in the near substation opens. The short-circuit current is removed from all the breakers at the distant station by the operation of the breaker feeding the short direct, except the distant breaker feeding the faulty trolley. The current through this breaker is suddenly increased because of the removal of the heavy short-circuit current from the high-voltage transmission line, and this breaker is operated, clearing the remaining short circuit.

Substation Bus Short Circuit. In the event of a short circuit occurring on the bus at a given substation, all breakers interconnecting the two substations carry equal exchange currents.

These breakers are therefore not operated by the high-speed trip, and the bus is isolated by the operation of a standard type of differential relay which opens all of the breakers connected to this bus. The feeders between substations are fed from the distant station and are not deenergized.

In the event a short circuit occurs in the step-down transformer, or in the high-tension line, the feeder breakers between the faulty substation and adjacent substation carry equal exchange currents and therefore do not receive a sufficiently high tripping current to operate. The faulty transformer or high-voltage line is disconnected from the bus by the operation of a standard differential relay around the transformer or reverse power relays in case of a high-voltage line short, both of which operate a circuit breaker on the low-voltage side of the transformer.

Conclusion

The development of both air break and oil break 12,000-volt a-c. high-speed circuit breakers, having a speed of operation comparable with the d-c. type, makes possible the same degree of selectivity and protection on a-c. electrified systems as has been obtained for a number of years on equivalent d-c. systems.

It is expected that this type of breaker will be particularly beneficial in minimizing inductive interference in signal and communication circuits.

Abridgment of

Extinction of an A-c. Arc

BY J. SLEPIAN[1]

Fellow, A. I. E. E.

Synopsis.—The transition from high conductivity to high resistivity which an a-c. arc undergoes on extinction is studied. Theory and approximate calculations are given for the rate of recovery of dielectric strength of the arc space for short arcs, and results are given of experiments on short arcs, and arcs in holes and slots in insulating material and insulating plates. The influence of chemical activity in arc gases is discussed. Factors contributing to the success of the a-c. oil circuit breaker are suggested.

I. Introduction

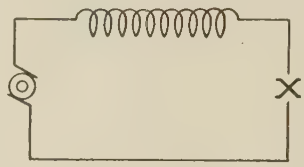
THE extinction of an a-c. arc as it is effected in switches and circuit breakers operating in a-c. circuits is fundamentally very different from the extinction of the arc in a d-c. switch. In the latter, by lengthening or otherwise, the arc is brought into such a form that it requires for its maintenance a voltage higher than is generated in the d-c. circuit. The current then decreases, and if the voltage required by the arc remains higher than the generated voltage, the current reduces to zero and the arc is extinguished. In the d-c. switch, then, it is important that the arc voltage be made and kept sufficiently high.

In the a-c. switch, however, the arc while it is playing takes a voltage which is generally smaller than the voltage generated in the circuit, and influences the course of the current only in a minor way. The current following its natural cycle comes to a zero value, and at such a moment, the arc extinguishes. In a very short interval of time embracing this moment of zero current, the medium containing the arc returns from its momentary condition of a comparatively good conductor, carrying current at a low voltage, to its normal condition of a comparatively good insulator supporting the full generated voltage of the circuit with passage of little current. It is this rapid transition at the moment of zero current, from the state of a highly conducting arc to the state of an insulating non-ionized gas which is important for the extinction of the arc in an a-c. switch. This transition must be made sufficiently rapidly if the arc is not to recur.

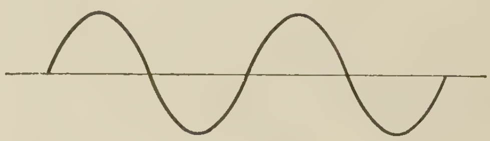
The study of this transition from arc to insulating gas at zero current is therefore not only interesting in itself but is important in that it may reveal principles leading to improvements in a-c. circuit breakers. This paper covers ideas on this subject developed by the author and his co-workers during the past few years.

2. Transition Time and External Circuit

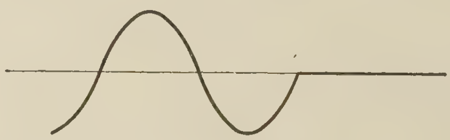
Let us first consider the question of the time available for the transition from arc to dielectric at the current cycle end in a circuit breaker operating in a practical reactive circuit. It is quite clear that this transition requires a finite time to be effected; that it cannot take place instantly. The conductivity of the medium carrying the arc cannot disappear suddenly. Being due, as we shall assume in this paper, to the presence of ions, time must be given for these ions to disappear, either by neutralizing their charges among themselves by recombination, or by discharging into the electrodes. Now how much time is available for this deionization in a practical circuit?



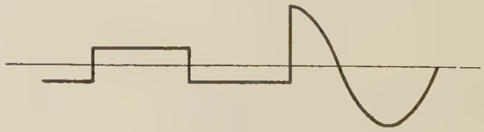
(a) Circuit with Ideal Reactor



(b) Generated Volts



(c) Current



(d) Arc Voltage

Fig. 1

Consider first the circuit of Fig. 1, consisting of an a-c. generator of large capacity in series with a reactor and an arc. Assuming that the arc voltage is small as compared with the generator voltage, the current will lag by nearly 90 deg., as in Fig. 1c. The voltage across the arc will of course be in phase with the current, as in Fig. 1d. Now if at the end of a half cycle of current, the arc should become extinguished and the current remain zero, the voltage across the electrodes would at once rise to the terminal voltage of the generator at that

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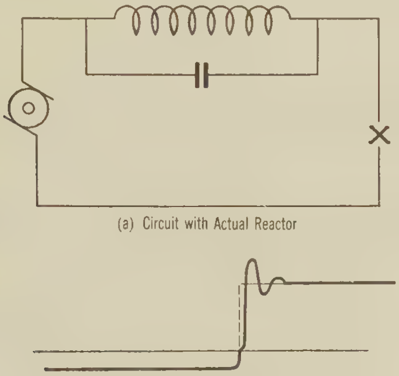
Presented at the Summer Convention of the A. I. E. E., at Denver, Colo., June 25-29, 1928. Complete copies upon request.

time, and because of the phase relationships, this would be the peak of the generated voltage. Hence, in such a circuit, no time whatever would be allowed for the arc to lose its conductivity at the end of a current cycle. If the arc becomes extinguished then, the space would immediately have to support the full generated voltage. An arc whose voltage is low relative to the generated voltage could not become extinguished in such a circuit.

However, it is only an ideal reactor which could function to produce the results just mentioned. Every actual apparatus must have electrostatic capacity as well as inductance. An actual reactor may be considered as acting as if it were an ideal reactor shunted by a small condenser, as shown in Fig. 2a. With such a shunted reactor, the voltage across the arc space will not rise instantly after arc extinction to the generator value, but will come on gradually as the reactor undergoes an oscillation. This is shown in Fig. 2b on a time scale much expanded as compared with Fig. 1. The time for the voltage impressed across the arc terminals to reach generated voltage is one quarter of the period of a natural oscillation of the reactor. This we may call the time available for the transition from the conducting arc to the insulating gas space.



(a) Circuit with Actual Reactor

(b) Arc Voltage

FIG. 2

This result can evidently be generalized, and we may say that the time available for transition is always as great, or greater, than a quarter of a period of free oscillation of the circuit external to the arc. In practical power circuits, the frequency of free oscillation may vary from the order of 100,000 cycles per sec. for the case of a current limiting reactor to only a few hundred cycles for the case of a very long transmission line. The time available for the extinction process in the arc, varies then from 2.5 microseconds to several thousand microseconds, depending on the character of the external circuit.

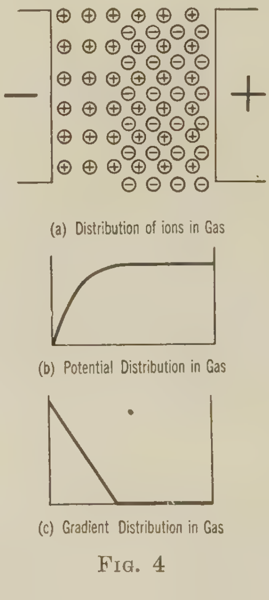
From this it would seem that under certain conditions the interrupting capacity of an a-c. switch may be greatly affected by the nature of the circuit in which it operates.

3. THE ELECTRIC GRADIENT IN AN IONIZED GAS BETWEEN CLOSELY SPACED ELECTRODES

In the last moments of the arc current and immediately following the current zero, the factors producing new ions have in general ceased their activity, and the ions already in the gas are diminishing rapidly in number by recombination. The rising voltage impressed upon the arc terminals by the external circuit acts therefore upon a gas space containing a diminishing density of ionization. Then the question naturally arises as to what is the dielectric strength of an ionized gas as a function of its density of ionization.

Important in the determination of the dielectric strength is the distribution of the electric gradient in the ionized gas. It is at once clear that the distribution will not be a uniform one. Although, initially, the densities of the positive ions and negative ions may have been everywhere equal, as a result of the application of the electric field this equality is disturbed, and space charges appear which cause the electric field to be distorted. At the cathode negative ions are repelled, and positive ions are attracted. A positive space charge therefore develops in front of the cathode which increases the electric gradient there. Similarly at the anode, a negative space charge and increased gradient also develop.

The exact calculation of this gradient distribution is very difficult, although much has been done on this problem by J. J. Thomson, J. S. Townsend, G. Mie, and others.[2] However, we may arrive at a sufficiently good approximation to the gradient distribution for our purposes in the following way. The mobility of the positive ions in the electric field is very small compared to the mobility of the negative ions, which are electrons in the cases in which we are interested. We shall neglect entirely therefore the motion of the positive ions and consider them fixed in space. We shall suppose however, that the negative ions move freely under the influence of the electric field.



(a) Distribution of ions in Gas

(b) Potential Distribution in Gas

(c) Gradient Distribution in Gas

FIG. 4

With these hypotheses, the effect of the electric field is to move electrons away from the cathode as in Fig. 4,

exposing a space charge of positive ions in front of the cathode with charge density, $n\,e$, where n is the number of positive ions per cm.^{3}, and e is the charge of an ion. This space charge causes a considerable portion of the impressed voltage to be consumed in the region next to the cathode. The thickness of the space charge will grow until all the impressed voltage is consumed in the cathode space. Assuming now that the diameter of the section of the ionized gas is large compared to the distance between the electrodes, we may apply Poisson's equation for one dimension, and taking $e = 4.77 \times 10^{-10}$ e. s. u., we readily arrive at the following relation:

Maximum gradient in space charge

$$\left(\frac{d\,V}{d\,x} \right)_{max} = 1.89 \times 10^{-3} \sqrt{V\,n} \qquad (6)$$

4. First Approximation to the Dielectric Strength of an Ionized Gas Between Closely Spaced Electrodes

As a first approximation we may assume that electrical breakdown of the ionized gas will occur if the maximum electric gradient in it exceeds a certain critical value. For the sake of definiteness, let us take for this critical value, a value approximately appropriate for air at normal pressure and temperature; namely 30,000 volts per cm. From equation (6) it follows that breakdown will occur when

$$\left(\frac{\partial V}{\partial x} \right)_{max} = 1.89 \times 10^{-3} \sqrt{V\,n} = 30{,}000 \qquad (8)$$

or

$$V = 2.52 \times 10^{14} \times \frac{1}{n} \qquad (9)$$

The breakdown voltage then varies inversely as the density of ionization, and is independent of the distance between the electrodes, so long as the electrode separation is greater than d, given by equation (4).

If the gas is at temperature T, we may assume, still as a first approximation, that the critical gradient varies inversely as the absolute temperature. Equation (9) then becomes

$$V = 2.52 \times 10^{14} \times \left(\frac{273}{T + 273} \right)^2 \times \frac{1}{n} \qquad (10)$$

5. The Decay of Ionization in a Gas

During the transition period immediately after the current zero, the dielectric strength of the arc space is rapidly increasing due to the decrease in the density of ionization, as given by equations (9) and (10). For an arc in the open, the ionization disappears principally by recombination. The rate of loss of ions by recombination is given by

$$-\frac{d\,n}{d\,t} = \alpha\,n^2 \qquad (11)$$

where α is the coefficient of recombination.* The solution of this equation is

$$\frac{1}{n} - \frac{1}{n_0} = \alpha\,t \qquad (12)$$

where n_0 is the density of ions at time $t = 0$. Where n_0 is very large, as in the case of the arc which we are considering, $\frac{1}{n_0}$ is negligible, and (12) becomes

$$n = \frac{1}{\alpha\,t} \qquad (13)$$

6. The Recovery of Dielectric Strength in the Transition from an Arc. First Approximation, Short Arc

Combining the results of sections 5 and 6, we get from equations (9) and (13) taking $\alpha = 7.6 \times 10^{-6}$

$$V = 1.9 \times 10^9\,t \qquad (14)$$

If we take into account the influence of temperature, assuming α varies as the inverse cube of the temperature and that the breakdown gradient varies inversely as the temperature, we get

$$V = 1.9 \times 10^9 \times \left(\frac{273}{T + 273} \right)^5 \times t \qquad (15)$$

Even allowing for the uncertainty of the numerical constants, these equations show that the recovery in dielectric strength is very rapid. In ten microseconds, if the gas is cold, the arc space is capable of withstanding several thousand volts. According to these equations, a low-voltage a-c. arc should extinguish in a circuit such that during the transition time the rate of increase of voltage applied to the electrodes is less than between 10^6 and 10^8 volts per sec.

7. Experiments on the Extinction of a Short A-c. Arc in the Open

Some time ago L. R. Golladay and the author made a study of the interrupting capacity of the multi-gap lightning arrester. This arrester consists of knurled brass cylinders spaced one-sixteenth of an inch apart, and some of the gaps so formed are shunted by resistors.

Tests on individual gaps were made in a circuit like that of Fig. 3 shown in the complete paper. The limiting value of R which would cause the arc to extinguish was determined for currents varying from 100 to 500 amperes, and voltages varying from 300 to 600 r. m. s. Tests were made both at 25 cycles and 60 cycles.

It was found that the limiting resistance varied inversely as the arc current, inversely as the frequency, and was approximately independent of the voltage. These results applied to equation (3) to show that $V_0\,\omega\,\frac{I_0}{I_r}$ was constant or that $\frac{d\,V}{d\,t}$ was constant.

2. *Handbuch d. Physik*, by Geiger and Scheel (published by Springer), Bd. XIV, p. 6.

*Townsend, *Electricity in Gases*, Oxford 1913, Chapter VI.

Thus the arc would extinguish if during transition the rate of increase of applied voltage was less than a critical value, and would persist if the rate of increase of applied voltage was greater than this value. This critical value was found to be 25×10^6 volts per sec.

It is interesting to compare this result with equation (**15**). A reasonable value to take for the temperature in the neighborhood of the cathode would seem to be the boiling point of brass or about 1200 deg. cent. Substituting in (**15**) we get $\frac{dV}{dt} = 0.4 \times 10^6$. If we take the melting point, or 940 deg. cent. we get $\frac{dV}{dt} = 1.1 \times 10^6$. These values are rather small compared to 25×10^6 but agree better with the results obtained in section 11, so that in these experiments perhaps a large part of the discrepancy is due to differences between the properties of zinc vapor and air, as the arc extinction probably took place in zinc vapor.

9. Arcs Through Holes in Metal Plates

From the theory so far given, and accepting the experimental value of 25.10^6 volts per sec. as the rate of recovery of dielectric strength of the arc space, it would seem that an arc in the open air is not a practical means for interrupting a-c. circuits of voltages higher than a few hundred volts.

It occurred to the author that conditions might be considerably improved if the arc was caused to play through small holes or openings in metal plates. In this way, ions could disappear by discharging into the metal plates during the transition time, instead of having to depend only on the recombination in the gas space, and so the deionization would be greatly accelerated. Space charges would be produced in the neighborhood of each plate which would consume some of the impressed voltage so that each perforated plate would act to a certain extent, like a cathode, as described in section 3. By having a number of these perforated plates in series, the rate of recovery of dielectric strength would be multiplied proportionally. It was believed, and subsequently substantiated, that the arc could play through the perforations of the plates for several half cycles (60-cycle current) without melting the metal, whereas it was believed that the arc terminals were necessarily molten.

Many confirmatory tests of these ideas were made by J. H. Neher and others.

10. Recovery of Dielectric Strength of Short Arcs at Low Voltages

Equations (**14**) and (**15**), developed for an arc in the open, with solid cathode, show that the arc space recovers dielectric strength at a constant rate immediately after extinction of the arc. Experiments at 300 to 600 volts r. m. s. with brass electrodes described in section 7, indicated that this rate of recovery was about 25×10^6 volts per sec. In deriving the equations (**14**) and (**15**) it was assumed that there was a definite critical electric gradient which, if exceeded at any point, would cause breakdown and restriking of the arc. However, it is well known that the mean gradient at breakdown of short spark-gaps increases rapidly as the length of the gap decreases; and that even for very short gaps, breakdown does not occur with less than a certain minimum value of voltage. For air, this minimum breakdown voltage is about 300 volts, or about 215 volts r. m. s.

It might be expected, then, that as the arc circuit voltage is reduced towards the value 215 volts, r. m. s., the mean rate of recovery of dielectric strength will increase very rapidly, and that for voltages below 215 volts r. m. s., it will be of a different order of magnitude than for voltages much above 215 volts r. m. s.

11. Experiments on Recovery of Dielectric Strength of Short Arcs at Low Voltages

The conclusions of the preceding section found confirmation in the following experiment. Sheets of copper were stacked together with 1/16-in. separators, and an arc of several thousand amperes in a circuit of adjustable voltage from 2300 volts down was blown into the structure, thus causing a series of short arcs to be produced between successive sheets. A suitably disposed magnetic field then caused these arcs to move in an annular path, and the arcs retraced this path so rapidly that practically no melting or burning of the metal sheets resulted. Details as to the construction of these sheets and the magnetic field will be given in a later paper. As a result of the lack of melting of the sheets, there was no flame of burning copper vapor to complicate the results as described in section 8, and it is probably correct to say that the arc extinction took place in air rather than in copper vapor.

The number of copper sheets was varied, also the circuit voltage, and the value of shunt resistance which would just cause the arcs to extinguish at the first current zero was determined. From these values of shunt resistance, the rate of rise of applied voltage was calculated by equation (**3**) and the curve of Fig. 6 was obtained.

For voltages per gap above 500 r. m. s., the mean rate of recovery of dielectric strength was 4×10^6 volts per sec. This seems to be very low compared to 25×10^6 volts per sec. observed by Golladay and Slepian for brass electrodes, but agrees better with the value calculated in section 7 thus indicating that air deionizes more slowly than zinc vapor. As the voltage per gap was reduced, the rate of recovery of dielectric strength increased reaching 300×10^6 volts per sec. at 180 volts per gap. For lower voltages per gap than this the rate of recovery could not be determined, as the arc would extinguish even when the shunting resistor was omitted.

The curve of Fig. 6 appears to have an asymptote at 165 volts r. m. s. corresponding to a peak of 235 volts.

The normal cathode drop for copper in air is 252 volts.[6] Thus the conclusions of the preceding section are confirmed.

12. Long Arcs and Arcs in Slots and Holes in Insulating Materials

Equations (**14**) and (**15**) state that the rate of recovery of dielectric strength of the arc space measured in total volts applied per second is a constant. In deriving this relationship it was assumed, however, that the linear dimensions of the cross-section of the arc space were large compared with the distance between the electrodes. This is certainly not the case for long arcs, or for arcs compelled to play in small holes or slots in insulating material.

A first study indicates that we may expect the arc to extinguish if during the transition there is an almost instantaneous application of a *gradient* of the order of two or three hundred volts divided by the hole diameter or slot width.

The curve of Fig. 8 obtained by R. C. Mason for slots and holes in soapstone one to two inches long roughly bears out this conclusion.

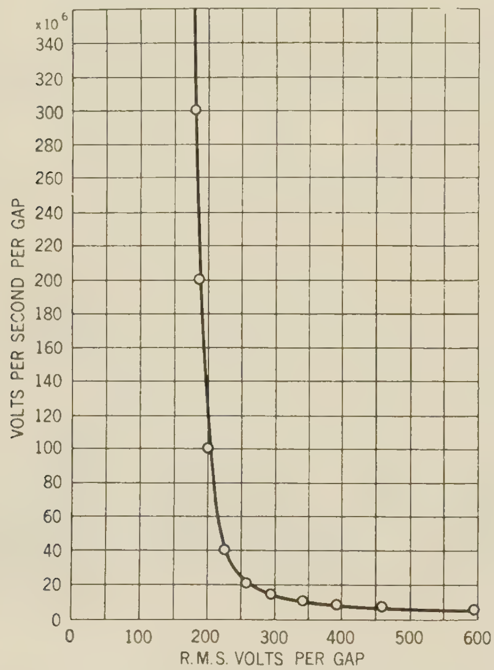


Fig. 6—Recovery of Dielectric Strength of Short Arcs in Air

13. The Oil Circuit Breaker

The success of the oil circuit breaker in high-power a-c. systems is probably due in part to all the factors discussed in the previous sections.

15. Acknowledgment

This paper gives an account of general ideas and principles developed on the extinction of a-c. arcs by a considerable number of men working with the author for the past few years. Many of the topics touched upon are of great interest in themselves, and it is hoped that they will be elaborated upon in later papers by the men who have carried on the work. Besides the men already mentioned in the paper, those who have contributed largely to the topics discussed are B. P. Baker, R. C. Dickinson, G. H. Cole, and F. C. Todd, but first

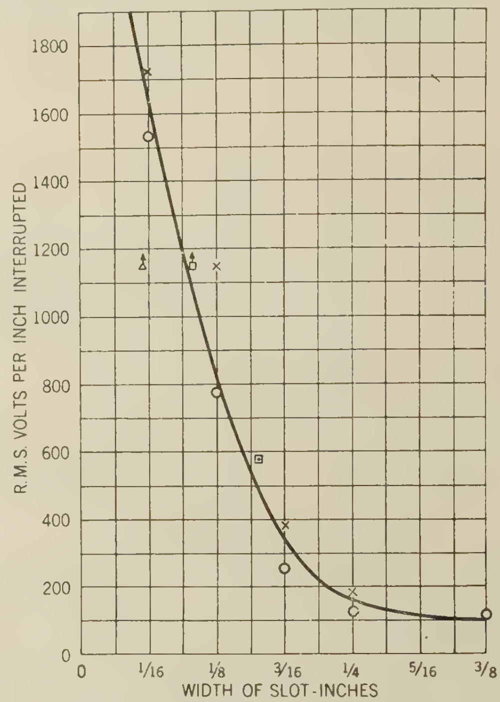


Fig. 8—Extinction of Arc in Slot

and foremost should be mentioned A. C. Crago, who, in spite of his untimely death in 1925, continued to influence the work through the wealth of ideas and inspiration he left behind him.

6. K. Rottgardt, *Ann. d. Phys.* Bd. 33, 1910, p. 1161.

AIRCRAFT LIGHTING TO BE STUDIED

Adequate and proper lighting equipment on an airplane is an important feature of the design of commercial aircraft that has a direct bearing on their safe operation in flying to avoid collision and in landing to avoid danger of crack-ups. For this reason a suggestion has been received by the Society of Automotive Engineers that a careful study be made of this subject with a view to establishing standardization of airplane lighting equipment and its arrangement on the plane.

Preliminary tests are in progress by L. E. Lighton, a member of the standards committee, on commercial airplanes that are being built, with the intention of placing the resulting data in the hands of a subdivision that will probably be organized.

It is felt that, with the rapid progress made within the last two or three years in the design and operation of commercial aircraft, the formulation of definite standards for aircraft lighting has now become a necessity.

Power-Line Carrier Telephony

BY L. F. FULLER[1] and W. A. TOLSON[1]

Fellow, A. I. E. E. Non-member

Synopsis.—*The inherent advantages of carrier-current telephony over high-voltage power transmission lines during the past five years have resulted in an unusually rapid development of this form of communication. To one who has not been constantly in touch with this rapid development, the necessity for the numerous types of carrier-current telephone equipment now available is not always apparent. This paper gives a brief outline of modern communication requirements in this field, the problems involved in providing this communication, and a brief outline of the different types of equipment now available to provide the required communication.*

COMMUNICATION requirements may be classified according to their complexities as follows:

1. Requirements which may be fulfilled by the use of a single channel. A system meeting these requirements is analogous to a single telephone line connecting all stations on the system. The practical limit to which such a system may be extended is determined by the volume of traffic handled.

2. Requirements making necessary the use of several communication channels on the same transmission lines, to handle more traffic than can be satisfactorily cared for by a single channel.

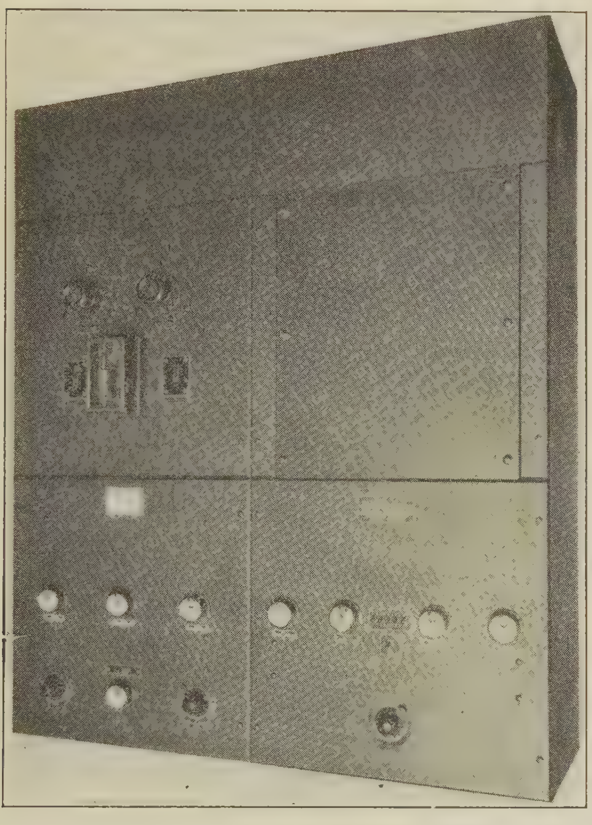


Fig. 1—Trunk-Line Carrier-Current Telephone Transmitter—Receiver Unit

3. Requirements making it advantageous to employ long "trunk" channels, each trunk station collecting traffic locally by private line extensions, or by secondary carrier channels from points not on the trunk channel.

4. Communication is often required between trunk or secondary carrier stations and isolated points, such as (a) patrolman's houses near the transmission line, (b) open air stations permanently located at isolated switching points, and (c) designated points for use of portable equipment.

In providing equipment to meet the communication requirements just outlined, many problems present themselves in connection with the operating requirements and the electrical characteristics of the transmission system.

The problems met in superimposing high-frequency currents on conductors carrying power at high potential may be divided under the two general headings of *Coupling* and *Transmission.* The problem of coupling high-frequency equipment to high-tension transmission lines was quite novel, and at the outset there was no experience available for guidance. Economic considerations naturally formed a large part of the problem, and are responsible solely for the development and design of several types of coupling capacitors, each type being best suited to a particular field of application.

The transmission of high frequencies over a power network involves very different problems from the transmission of low frequencies over the same network, or from the transmission of high frequencies over telephone conductors. It has been necessary, therefore, to develop a radically different technique for handling power-line communication problems.

The ideal line for the transmission of high frequencies would consist of a single high-voltage transmission line which has no directly-connected branch lines and which may be terminated at its ends in an impedance equivalent to its surge impedance. Such an ideal condition is very seldom realized or even very closely approached in actual practise. Branch lines produce two effects on a carrier communication channel; first, due to the fact that the branch line must be energized as well as the main transmission line a loss of some carrier energy is incurred; and second, a branch line gives rise to reflection. When the carrier-frequency voltage reaches the remote end of the branch line, it is reflected back toward the point of origin and arrives at that point with a phase relation (with respect to the original voltage) which will

1. Both of the General Electric Co., San Francisco, Calif.

Presented at the Pacific Coast Convention of the A. I. E. E., Spokane, Wash., Aug. 28-31, 1928.

depend upon the length of the branch line and the frequency of transmission. This reflected wave may therefore either aid or oppose the original voltage. Fortunately, however, in most practical applications the two above effects are either too small to seriously affect communication, or may be avoided to a large extent by a proper selection of operating frequency. Where necessary, the effect of branch lines may be eliminated from the carrier circuit by means of high-frequency trap circuits.

Frequently, it becomes necessary to communicate over a transmission line which is broken permanently by a voltage transformation or frequency changer, or which may be opened by switches. In these cases, it is necessary to provide a means for transferring the carrier energy around the break in the power circuit.

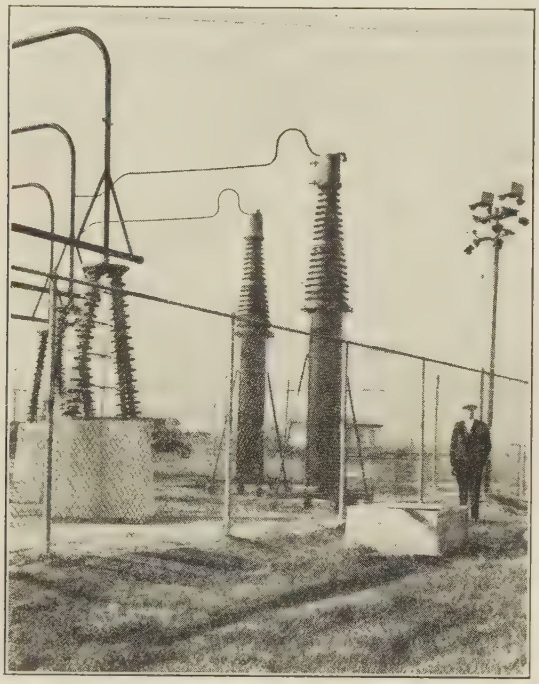


Fig. 2—Coupling Capacitors for Power-Line Carrier Telephone

The same problem is involved in transferring a communication channel from one transmission system to another.

In some cases, the communication distances involved are such that a power in excess of that supplied by the normal transmitter is required. This problem can usually be solved in either of two ways: by increasing the power of the transmitter until sufficient energy is received at the remote point, or by using carrier-current repeater equipment near the electrical center of the transmission system to raise the energy level of the received signals to their original value, and re-transmit them along the transmission system. The latter method has three distinct advantages; first, the total power required to transmit a signal over a long distance is less if a repeater is used than if the signal is transmitted directly; second, the repeater requires no abnormally large output from any of the transmitters and therefore does not increase interference between carrier channels nor greatly increase the probability of interference with broadcast receivers; third, the two remote communicating stations may be using entirely different carrier channels, the transfer in channels being made at the repeater.

It is evident from a consideration of these problems that an equipment designed to provide absolutely satisfactory service for transmission over telephone conductors might be entirely inadequate to provide communication over a power network.

The following description of the available carrier-current telephone equipments developed by the company with which the authors are connected will serve as an indication of the methods used in meeting the communication requirements and in solving the problems related thereto.

Among all types of apparatus complete intercommunication is provided, a single frequency band being employed for each two-way channel.

Primary Station Equipment

This equipment has been developed to meet the requirements on trunk channels. The necessary facilities for efficient and economical operation of trunk channels are provided in the following operating features:

1. Full automatic operation is provided from any operator's phone, the necessary procedure in placing or receiving a call being practically identical with that of a conventional wire-line automatic telephone system.
2. A maximum of ten two-wire telephone extension lines may be connected to each station equipment, each line having complete control of the carrier station and being selectively called from any carrier station on the same system. Provision may also be made to allow communication from other telephones connected with private branch exchanges, either manual or automatic.
3. Each incoming telephone line has exclusive and private use of the carrier equipment, and the conversation cannot be interrupted by a party on any other incoming line. An exception to this is that dispatchers' lines, or other designated lines, may be connected for preferred service, thus permitting the operators at designated telephones to interrupt a conversation on any other line and request the use of the carrier channel.

Parties on lines not connected for preferred service receive a "busy tone" if they attempt to place a call when the station equipment is in use.

4. Four-wire circuits may be employed if the noise level on a telephone line is so high as to make it unsuitable for a two-wire extension. When a four-wire circuit is used, the signal input to the line from the operator's telephone instrument may be raised to any desired level by means of simple amplifier equipment, and thus the ratio between signal and noise may be increased. The strength of the audio-frequency input to the carrier

set may be reduced by means of adjustments at the carrier set, so that when an amplifier is used at the operator's end of the line, satisfactory operation may be obtained, even though the noise level on the line is quite high. The service provided over a four-wire circuit is the same as for a two-wire circuit.

5. Provision is made for the application of "inter-system" attachments, to provide communication from the same station equipment over either of two separate carrier channels. Wire-line extensions from a station so equipped may receive or transmit calls selectively over either channel, the selection of channels being entirely automatic. While an operator is engaged in a conversation over one channel, he can receive calls over the other channel.

6. By means of a suitable attachment, high-tension telephone lines can be used for extension service, the operation secured on such extensions being the same as that for "quiet line" extensions.

7. Two primary equipments may be used together for repeating signals on very long channels, or for transferring signals from one transmission network to another. This service will be discussed under a later heading.

Secondary Station Equipment

Some communicating points do not require all the operating features provided in a primary equipment. A secondary station equipment has been developed to meet this condition economically. Four wires are required for connecting each telephone instrument to the set. When several telephone instruments are used, code ringing is employed. Full selective ringing may be provided by the use of one additional conductor between the set and each instrument.

The apparatus is designed to operate normally from 110-volt a-c. power supply, but may be made independent of the a-c. supply by the addition of a motor alternator operating from a storage battery. Where no a-c. supply is available, this storage battery may be charged from a gasoline-engine-driven generator.

Booth Equipment

This equipment is suitable for communication from isolated points where the communication distances are moderate. It is designed for operation either from dry cells or from a 110-volt a-c. supply. The equipment is mounted in a weatherproof case and when battery operation is used, may be installed on a tower or other convenient location exposed to the weather. This application is intended primarily for use by line patrolmen or service crews, and intermittent service only is provided. When this equipment is used with a-c. supply, full time operation is provided and it is suitable for installation in switching stations and line patrolmen's houses. The equipment includes a small 60-cell storage battery which provides emergency operation during failure of the a-c. supply. The communication provided by this equipment is simplex; that is, the operator employs a push-button on the hand set to change from "receiving" to "transmitting" position.

Portable Equipment

This equipment is designed to provide communication between any station equipment and fixed points along the transmission line within a radius of approximately 30 mi. It is a self-contained and extremely compact transmitter receiver unit, weighing approximately 15½ lb., and provided with shoulder straps to facilitate carrying. The communication provided is simplex.

Intersystem Equipment

This equipment is designed to operate as an attachment to the primary station equipment, permitting the operation of such an equipment on either of two communication channels. A load dispatcher may thus communicate selectively over either his own communication system or that of an interconnecting system. As an alternative, the load dispatchers of two interconnected systems may be provided with a channel separate from those used for system communication.

By-Passing Equipment

When it is necessary to transfer the carrier energy around a transformation, open disconnecting switch, or other discontinuity in the carrier circuit, a by-pass equipment consisting of a series of resonant circuits is employed. Since no vacuum tubes or moving parts are employed the equipment requires only periodic inspection and is therefore suitable for tower mounting at isolated or unattended points.

Carrier Current Repeater Equipment

In discussing the primary equipment, mention was made of the fact that two carrier sets may be used together to comprise a repeater assembly. Such an equipment may be installed to serve two distinct purposes: First, it may be used to raise the energy level on a carrier channel and therefore permit much greater communication distances; and second, it may be used to connect two otherwise independent communication channels and permit either completely independent operation of the two channels or complete intercommunication between stations on the two channels, as desired.

When operating as a normal repeater, the equipment functions as follows: The incoming modulated carrier is received and demodulated in the normal manner. The signal component is then amplified and impressed upon the transmitter operating over the outgoing channel. The apparatus is so designed that a signal which has been received and re-transmitted by the repeater cannot pass back through the repeater to the side from which it was originally received. This is accomplished by apparatus so designed that when one of the transmitters begins to function, the output circuit of its associated receiver is blocked. All tendency toward "feed-backs," which would result in oscillation

or "singing" of the repeater circuit, is thereby eliminated. The operations for repeating the signals are identical for both directions.

The repeater equipment is in the operative condition only while actually in use. It is started automatically from a calling station as follows:

An operator desiring to communicate through the repeater station first dials the "repeater exchange" number. This number serves to start the motor-generator set and place the repeater in operation. Any further numbers dialed by the calling operator are repeated over the outgoing channel. The ensuing conversation is similarly transferred from one channel to the other.

When the repeater is placed in operation by an incoming call, a time delay circuit is energized to maintain the apparatus in an operative condition for a definite time interval after the last signal is repeated. At the end of this time interval the repeater apparatus is automatically shut down, thus effecting a saving in operating cost and increasing the operating life of the apparatus to that of a normal station equipment. The time delay feature is provided to prevent the repeater shutting down during pauses in a conversation. The length of time delay is adjustable within wide limits to suit local requirements.

The operator at the repeater station may be provided with automatic selective control, permitting communication over any channel selectively, or over two channels simultaneously. He may monitor the conversations on either side of the repeater or passing through the repeater, or may enter into these conversations.

The operation of a repeater in connection with an intersystem attachment is the same as that of a normal repeater except that the "repeater exchange" number, in addition to placing the apparatus in service, selects the proper outgoing channel.

High-Tension Telephone Line Extension

As an extension to a primary station equipment, it is sometimes desired to use a high-tension telephone line; that is, a telephone line so situated in the proximity of a high-voltage transmission line that the extraneous voltages induced in the telephone line are relatively great. Such a line is unsuited for direct connection to a primary carrier set. In order to eliminate the effects of power frequency induction, a special form of extension equipment may be employed on any high-tension telephone line over which successful voice-frequency communication may be provided. This type of extension employs carrier-frequency transmission from the remote operator to the primary carrier set, and voice-frequency transmission from the set to the operator.

The use of a high-frequency carrier for transmission from the remote operator to the station apparatus makes it possible to eliminate power-frequency voltages from the input to the station transmitter, by means of filters which do not pass the low frequencies. The use of these filters also makes it possible to separate the incoming from the outgoing signal without the use of balancing networks such as are used with voice-frequency telephone repeaters. The amplification afforded by this type of extension apparatus is such that the length of telephone line that can be used is much greater than in the case of the usual two-wire extensions as designed for quiet lines.

The telephone line used in connection with a high-tension extension does not necessarily constitute a complete d-c. circuit, and can be used, therefore, with the normal insulating and drainage transformers and protective devices. The protection afforded the operator from voltages induced on the telephone line by power circuits or lightning is even better than that provided when employing such a telephone line in the normal manner.

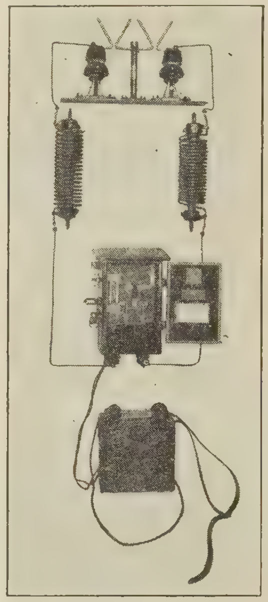


Fig. 3—Portable Carrier-Current Telephone

With connection box and protective equipment for coupling unit installation.

Multiplex Carrier Channels

Because of their peculiar advantages, the demand for additional uses of carrier current channels is growing. These are for relaying sections for line, distant control of switches, telemetering and frequency transmission. Fortunately, a pair of coupling capacitors may be used for the simultaneous transmission of more than one carrier frequency. Lines using capacitors for carrier telephony at the outstart are now being equipped with these later developments.

The number of additional channels it is possible to operate without interference is limited, and it is obviously most desirable to employ but one frequency per channel. The development of the single-frequency duplex-carrier telephone some years ago has been most helpful in this regard.

New Uses for Carrier Current

In general, a carrier-current channel can be made to accomplish what would otherwise require a separate pair of wires, without the investment and maintenance charges of the latter. When the distances involved are sufficient these factors result in distinct monetary and operating advantages in favor of the carrier channel.

New applications are arising daily. An interesting example is the case of a large pumping load supplied by one power system, but scattered over a large territory. These motors may be controlled at will by carrier current over the distribution system, thereby making it possible to reduce the peak and improve the load factor.

In another instance, it is desired to transmit the frequency of one generating station to another, and carrier current offers a ready solution. There are, no doubt, numerous other operating situations wherein carrier-current methods present the best engineering solution.

Abridgment of

Automatic Mercury Arc Power Rectifier
Substation on the Los Angeles Railway

BY L. J. TURLEY[1]

Associate, A. I. E. E.

Synopsis.*—The development of the commercial mercury arc rectifier is outlined briefly in this paper and the advantages which led to its adoption in a double-unit automatic station recently installed by the Los Angeles Railway are given. A report is made of the very satisfactory operation which has resulted. There is a description of the station, and the methods of operation and maintenance are presented.*

* * * * *

Introduction

THROUGHOUT this outline we shall draw deductions from comparisons with the synchronous converter. We shall present important factors which led to decision in favor of this type of equipment, give added proof of the rectifier's satisfactorily meeting a railway load requirement as gained from our experience with a short-time operation of the double-unit automatic substation recently installed by the Los Angeles Railway in Inglewood near the city of Los Angeles.

Although the basic structure of present day rectifiers shows no marked advance over early developments, a variety of problems arose, not only with respect to the design but also involving the protection and operation of this type of apparatus. These broadened the field of exploration for considerable added and novel improvements—especially with the auxiliary equipment. The speed of all this accomplishment has been reflected in a final solution embodied in the present type of rectifier, now under discussion. Thus, during the last three years, we have witnessed many pioneer installations of European and American makes of equipment, scattered on diversified railway loads. Showing a rapid growth in popularity and producing a considerable degree of confidence, due to the rectifier's general simplicity, compactness, and reliability.

As greater familiarity with this equipment developed, many other important factors in its installation and operation appealed to the operating engineer. A study of conditions which entered into a problem for a specific class of application and the results from its short-time operation placed this rectifier in a favorable position and demonstrated its relative advantages to supplement synchronous converters where such application involved load centers of low load factor and heavy momentary peaks.

Finally, its insensitiveness to short circuits, its adaptability to full automatic control, its comparative noiselessness of operation, its ability to carry sustained short-time overload, its absence of moving parts (excepting small auxiliaries), and the elimination of the attendant troublesome features commonly experienced in the operation of large rotating machines, all substantiate the claims advanced by its proponents and constitute such valuable and economical assets as obviously to insure for the rectifier a most favorable recognition by the more enterprising engineers of the railway industry.

There are, however, a few apparent disadvantages. The penalty of considerably lower power factor may be serious with some installations; but this is more than offset by a high and favorable all-day efficiency factor, when based on over-all conditions, in comparison with a synchronous converter installation of similar rating and operating under similar load requirements. The complaints from sections, of interference with communicating circuits, are comparatively few and are fast disappearing. The characteristic high-harmonic current and voltages as generated by a rectifier are subject to correction at very little expense. Surely, the 10 to 15 per cent higher first cost over synchronous converters would seem to be justifiable only to cover a certain amount of development cost common to all new introductions. Usually quantity productions soon absorb

1. Electrical Engineer, Los Angeles Railway Corp., Los Angeles, Calif.

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or wipe out the excess in such overhead costs. How soon this lower price is to be realized by the users of this equipment would seem to depend upon the rate with which the manufacturers expand their design and facilities to offer larger ampere capacity units for active competition throughout the entire range of synchronous converter applications.

General Description of Building and Equipment

The exterior of this steel-framed reinforced concrete building, presents a striking similarity to a chapel of typical Spanish architecture. The blind windows and small entrance door, suitably fitted, prevent the entrance of dust except as it may be carried through the regular air channels which are provided with air filters.

The interior of the building is artificially lighted and effectively air cooled. The equipment consists of a double 500-kw. unit complete, the protection and operation of which are under full automatic control. The feeder panels are similar to the standard automatic high-speed circuit-breaker equipment and control scheme as installed in other automatic substations on this railway property. Fig. 1 gives an interior view of the station, showing the position of the rectifier.

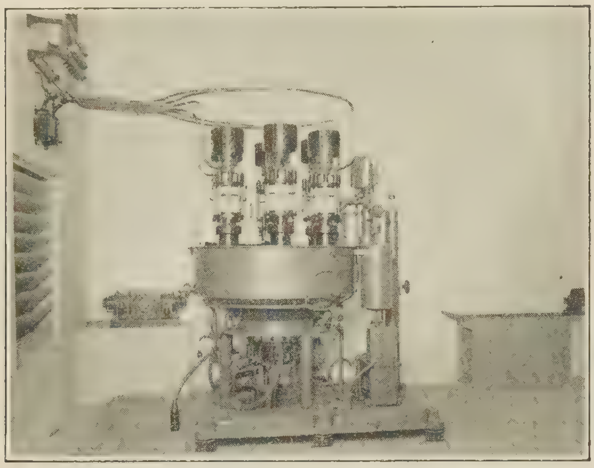


Fig. 1—Number 1 Unit, 500-Kw. Rectifier

Application

The entire length of railway line to be fed from this station extends over six miles beyond the intermediate section of the railway system. Except for special events, the car service normally rendered had a peak headway of four minutes, graded to 25 min. for lighter load periods. The low average energy consumption and the resultant low station load factor, coupled with intervals of 30 to 60 min. between load demands during early morning hours, (which would create a possible frequency of starting and stopping of station equipment), were essential factors of operation that gave the rectifier more favorable comparison in applying its electrical characteristics as to efficiency, readiness to serve, and simplicity in starting.

The experience obtained from many years of operation with automatic control applied to synchronous-converter railway substations naturally led to choosing an automatic application for this rectifier station. It is simple, effective and surprisingly reliable, and has become generally adopted. Those chief factors that are usually presented in favor of automatic control—improved labor conditions, improved service continuity, and reduced operating expense—may be considered as the salient factors derived from operation of rectifier equipment.

Weights

The total weight of the rectifier complete installation is only 400 lb. greater than for synchronous converter units. The rectifier itself weighs one-third that of the converter and did not require any special foundation, except as given by a six-inch cement flooring.

Rating

With the exception of their momentary load ability, the rating of these 500-kw. unit rectifiers is equal to that of synchronous converters, since they are based upon the same standard method of rating such equipment for railway application.

Although a converter would ordinarily carry its two-hour overload rating of 150 per cent load continuously, yet the sustained high temperature would naturally shorten the life of the insulation. On the other hand, the rectifier, exclusive of transformers, could be expected to operate continuously at its two-hour overload rate without shortening its life.

The momentary load of one minute duration allows the converter 300 per cent load and the rectifier, 200 per cent load. This difference is attributed to the rapidity with which the maximum allowable temperature rise affects operation. The converter operates through a wide range of temperature allowances. Due to its thermal capacity, a 300 per cent load superimposed for one minute upon its continuous load temperature does not raise the temperature of the hot spots of the machine sufficiently fast to do injury before the load has been reduced. The rectifier works with temperatures of a very narrow range has low thermal capacity and is affected by low as well as high temperature. A one-minute load of 300 per cent creates such a rapid rise of temperature that the heat affects the performance and might damage the anode tips.

The instantaneous overload of a converter is limited usually by its commutating capacity, and when such limits are reached, there is a possibility of damage to the machine, locking it out of service, especially if a flash-over prevails. The rectifier is not so affected by instantaneous overloads, even of short-circuit proportions. Under certain conditions, the rectifier may occasionally "arc back," which results in practically no damage; at least not enough to prevent it going back into operation within a few seconds.

Efficiency

A large amount of the power used by the auxiliary apparatus is foreign to a synchronous converter installation. This fact requires a comparison of efficiency to be made on over-all conditions. The manufacturer's

curve on efficiency as estimated for this installation is given in Fig. 2. A certain number of check points are plotted on this curve as actually obtained by using properly tested a-c. and d-c. watthour meters, which power includes consumption by all auxiliary apparatus. On an average 24-hr. load of 200 kw., each rectifier unit in this substation has an efficiency of 94.0 per cent against 90.0 per cent for a converter of corresponding size.

Power Factor

The operating power factor for Inglewood during the normal 18-hr. range of load remains about 86 per cent. It is lower than the manufacturer's estimate, doubtless due to the compounding features, the drooping characteristic of the power transformer, and the combined effect of the a-c. supply voltage. In fact, with compound winding, the power factor is about 4 per cent lower than for shunt-voltage regulation. Fig. 3 shows power-factor curve as given by the meter on the primary side of the circuit for shunt and compound operation.[2]

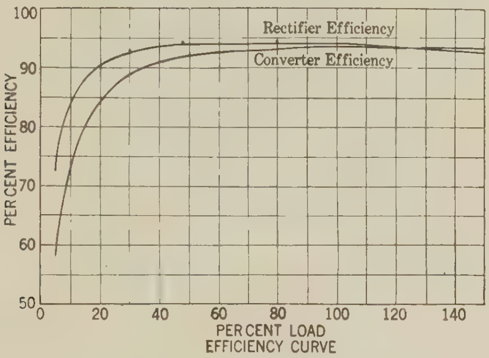


Fig. 2

Regulation and Voltage Characteristics

Voltage curve, (Fig. 4) includes regulation for both shunts and compound voltages with this installation. The compound features of the combined unit give a 2 per cent regulation. The a-c. supply voltage is 3 per cent above normal and results in a 3 per cent higher d-c. voltage than originally calculated.

Telephone System Interference

Tests were conducted for inductive interference on the various communicating circuits that parallel the trolley line for several miles in both directions from the substation. Perfect satisfaction was expressed by the telephone company engineers on the developed freedom from noise, and it was surprising to note that there was less interference with the rectifier in operation than with the noise experienced from operation of the motor-generator sets in the adjoining manual station.

This was accomplished by connecting between station bus and rail ground, a filter system tuned to resonance at the characteristically pronounced frequencies developed by the rectifier equipment.

2. The accuracy of such a method for measuring true power factor has been questioned, due to distorted wave form affecting the instrument and giving a much lower indication than the wattless component.

Ventilation

The Inglewood Station is provided with forced air for transformer cooling and general station ventilation. During periods of hottest summer days, at 40 per cent load factor, general room temperature averages 3 deg. cent. rise above outside temperature. Fig. 5 shows air temperatures with 24-hr. load curve.

Water Cooling System

Tap city water is used, averaging 20 deg. cent. with discharge of waste water into the cesspool. The total 24-hr. water consumption equals 825 cu. ft., giving a rate of 0.9 gal. per min. per 100 amperes, which is

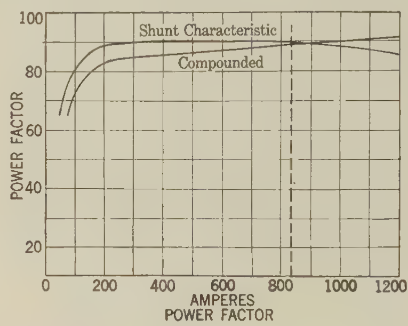


Fig. 3

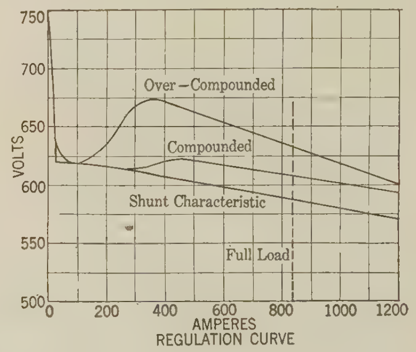


Fig. 4

considerably higher than the manufacturer's estimate, but could be reduced without fear of over heating.

Operation

With a rectifier, reverse current can occur only at the instant of the arc back or a short circuit of the electrode. If this occurs, a high-speed breaker, connected for such reversed direction of current, will trip-out, disconnecting the unit from load, and reclose within a few seconds. Three consecutive openings of this breaker locks out the unit. There have been no arc backs with the Inglewood Substation rectifiers.

There are conditions in operation which develop a high-voltage kick and which might do injury to a transformer windings. Protection against this possibility is obtained through absorption by connecting a group of condensers with resistors across one leg of each Y of the power transformer low-tension windings and with the interphase transformer; also, as added protection through short-circuiting, a pellet type of arrester parallels each of these groups.

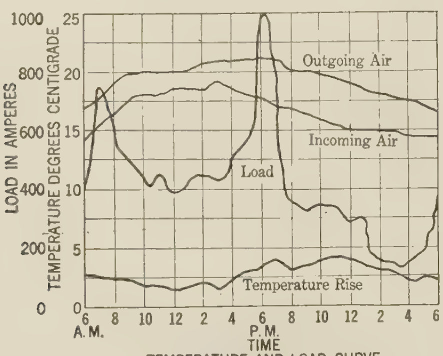
The number of control devices, switches, etc., re-

quired for the complete two-unit rectifier has been compared with those required for a synchronous converter installation.

For the rectifier, there are one-half the number of main current-carrying parts, practically the same number of protection features, with a slightly greater number of auxiliary devices, totaling an equal number for both types of units.

Inspection and Maintenance

Regardless of an equal number of control devices and switches, which consist of a few special pieces of apparatus and devices of delicate construction, the frequency or general routine inspection for this substation has been conservatively established on an interval of every two weeks. A daily visit of one hour is made to take necessary meter readings, check general state of small rotating equipment, and force the operation of



TEMPERATURE AND LOAD CURVE

Fig. 5

the vacuum pump against its automatic control so as to assure a faster rate of seasoning-in of the vacuum tank. This practise is not absolutely necessary, but it is the method of giving this new type of equipment all the attention it deserves. This inspection rate is considered ample and commensurate with the service various parts are called upon to render. The automatic converter substations of this company require weekly inspection and a two-hour daily visit, which includes some cleaning up. For the converter, this rate is necessary regardless of the importance and assurance of long familiarity with equipment and control principles.

Aside from cleaning, adjusting, and testing regular parts of the equipment, it is found that the time and attention given to the vacuum pump, vacuum relay, and water regulator are no more of a special nature than required by the brush-raising device and master controller of the converter substations.

Every six months, and taking two men six hours, it is planned to clean the mercury in the anode heating chamber and to replace all gaskets. This does not break the vacuum in the tank.

All too often doubt has been expressed that the maintenance cost of the rectifier and its auxiliaries, especially that cost incidental to the vacuum pump, would not be less than the items required to cover actual labor and cost of material for repairs to the synchronous converter and its coordinated equipment. In fact, overhauling the rectifier has been heralded as taking longer than the necessary work on the synchronous converter. These doubts and claims have not come from operating engineers using the rectifier equipment.

The vacuum pump and its appurtenances are rigidly and sturdily constructed and should give less trouble than the small time-aged motor-generator set used for exciter purposes. All the essential spare parts for the rectifier cost less than the average carried for six converter stations of this company. Since these rectifiers had proper care at the initial drying-out period and developed no sign of trouble during operation, the most that may be expected in the way of maintenance attention would be that following a two-year period of operation, at which time the total expense of labor and material for overhauling all anodes, tank, vacuum seals, vacuum pump, and time necessary to dry out, should be far less than the usual attention to converters, in grinding commutators, attention to new brush fit, changing oil, and the checking of bearing alinement, together with the occasional reinsulating of windings.

Considering that there are no intermediate starting or running a-c. contactors, brush-raising devices; no checking of polarity and synchronizing requirements; no massive moving parts and oiled bearings subject to excessive strains of frequent starting, with no carbon and copper dust developing to be scattered throughout the station with high velocity of circulating air, it is obvious there should be no surprise at the present claim and at the eventual proof of considerably lower cost for inspection, cleaning, and maintenance of rectifier equipment.

TABLE I
ESTIMATED SAVINGS

Excess cost of rectifier equipment over converter as per contract	$7,450.00	
Annual fixed charges at 12 per cent		$894.00
Excess cost of converter installation for foundations, air ducts, air equipment, sound proofing, etc	3,540.00	
Annual fixed charges at 12 per cent		425.00
Difference in costs	3,910.00	469.00
Estimated yearly labor savings for rectifier	604.00	
Estimated yearly power savings for rectifier	525.00	
Total estimated savings for rectifier		1,129.00
Total net annual savings for rectifier		660.00

Savings

Table I has been prepared showing estimated savings in building cost, energy loss, and labor for inspection, in comparison with the synchronous converter.

The net savings in favor of the rectifier, amounting to $660.00, will cover the excess cost and fixed charges of the rectifier in approximately six years, after which it is estimated that the total annual saving of $2500.00 will carry 6 per cent interest charges on 50 per cent of the entire investment.

Abridgment of

Electrical Machinery

ANNUAL REPORT OF THE COMMITTEE ON ELECTRICAL MACHINERY

In view of the length of the complete report and the difficulty to condense its values into a four-page JOURNAL abridgment, it has been decided to use the illustrations only, with the explanatory captions. Each illustration represents some unique feature of progress made during the year.

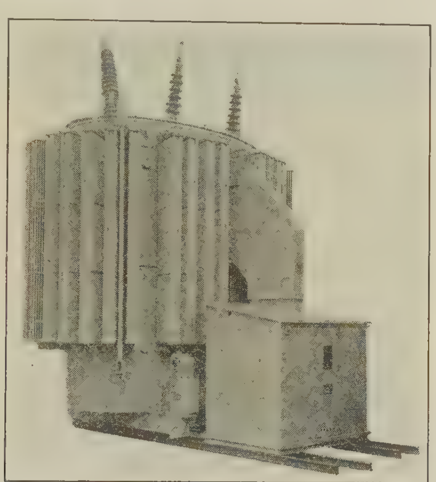


FIG. 3—33,333-KV-A. POWER TRANSFORMER, 60-CYCLE, SINGLE-PHASE 2 20/69/13.2-KV.

With load ratio control for the 69-kv. winding. Largest transformer yet built

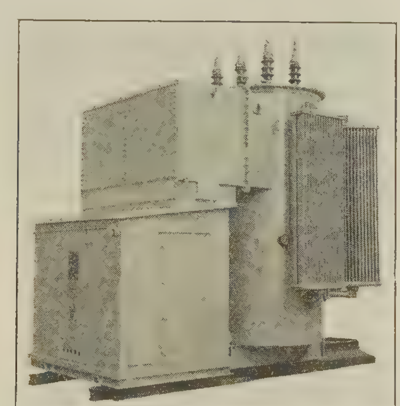


FIG. 4—10,000-KV-A. POWER TRANSFORMER, 60-CYCLE, SINGLE-PHASE, 35,000-VOLT

With control for 20 per cent voltage regulation, using a new scheme of connections between main and auxiliary transformers

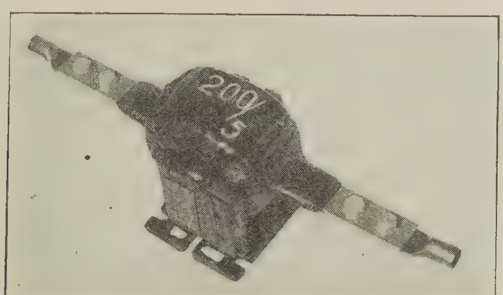


FIG. 11—PRECISION CURRENT TRANSFORMER USING HYPERNIK STEEL

Which decreases the errors in measurements on account of low losses and good permeability in the core material

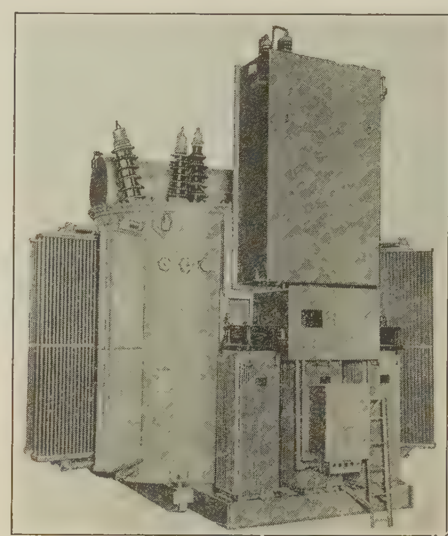


FIG. 7—6850-KV-A., THREE-PHASE POWER TRANSFORMER 66,000/60,000 VOLTS

With 43 per cent voltage regulation by means of taps and induction regulators. A flexible combination which provides for variable ratings by changing ratings of regulators only

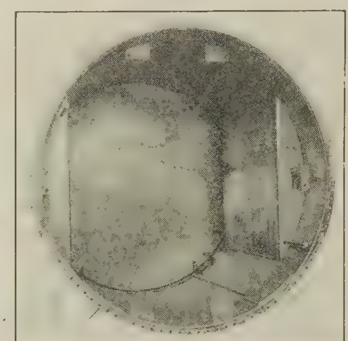


FIG. 9—INTERNAL TANKS TO PROVIDE MORE SPACE FOR EXPANSION OF INERTAIRE AND THUS REDUCE THE AMOUNT OF BREATHING

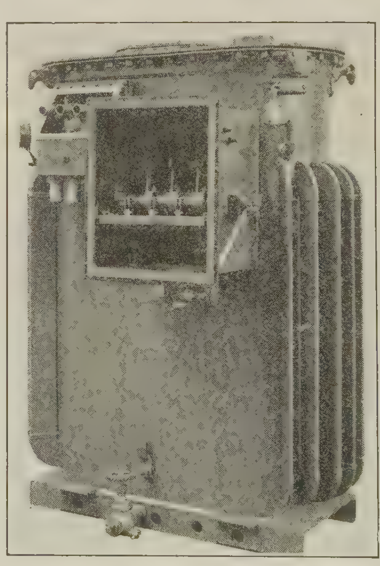


FIG. 10—THREE-PHASE NETWORK TRANSFORMER

Equipped with junction boxes and cable disconnecting and grounding switch in primary junction box. Junction boxes open. Switch in operating position

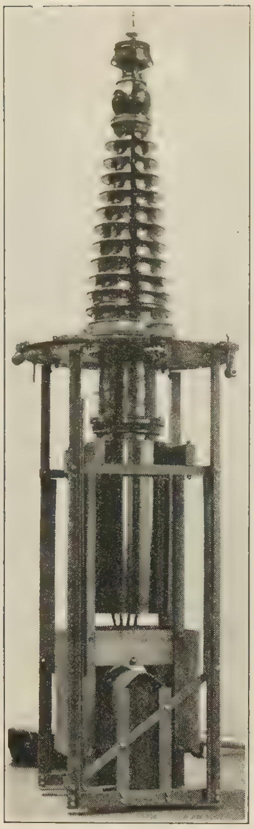


Fig. 12—Instrument Current Transformer for 155,000-Volt Circuit. 200/400 Amperes

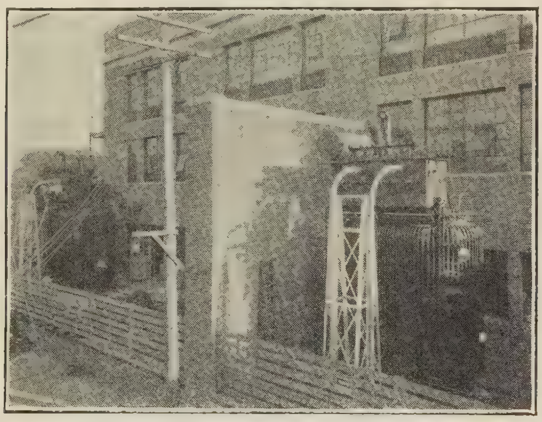


Fig. 18—Installation of Pothead Transformers which Combine the Cable Pothead with the Top of the Transformer

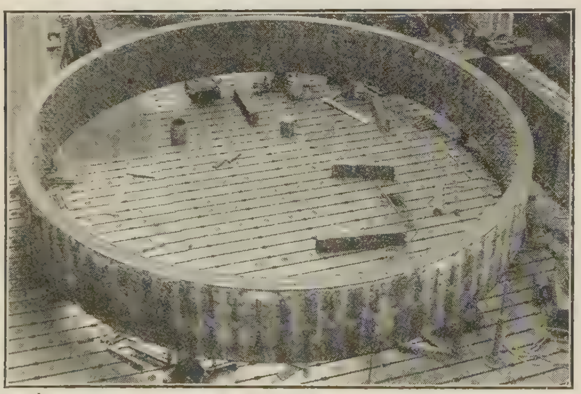


Fig. 20—Assembled Rotor Rim for 40,000-Kv-a. Conowingo Generator

This rotor is exceptional in size and is made of plates bolted together

Fig. 14—Portable Testing Outfit for Checking the Quality of Transformer Oils

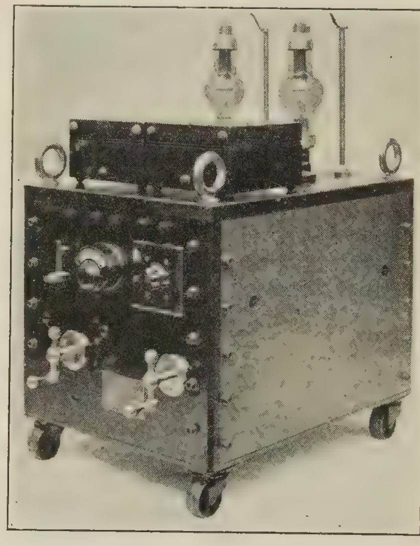


Fig. 17—D-c. Cable Testing Set. 7500 Volts End Grounded

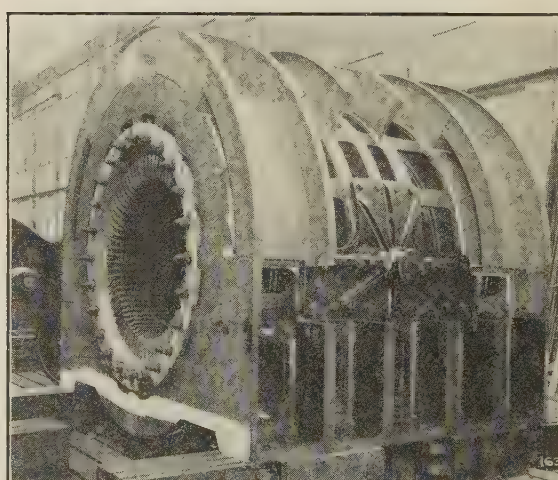


Fig. 23—Turbo Generator Stator with Ventilating Outer Skeleton Partly Assembled

This construction allows the stator to be shipped complete with windings by removing the feet and ventilating shell, which decreases the width to the maximum shipping width allowable

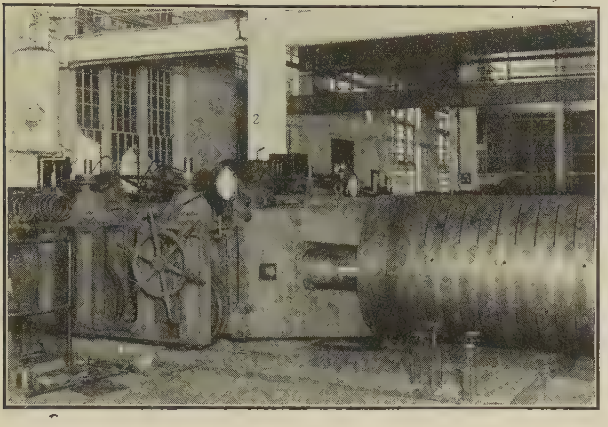


Fig. 24—Hydraulic Bolt Puller for Tightening Through Bolts in Plate Type Turbo Rotor, Which Insures the Correct Tension on Each Bolt

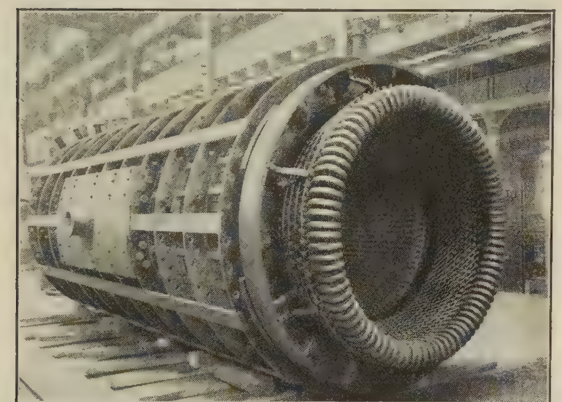


Fig. 25—Inner Skeleton Structural Frame for Turbo Generator

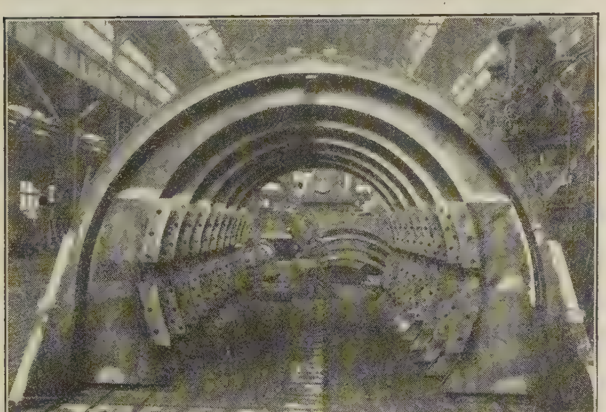


Fig. 26—Outer Skeleton Structural Frame for Turbo Generator in Fig. 25

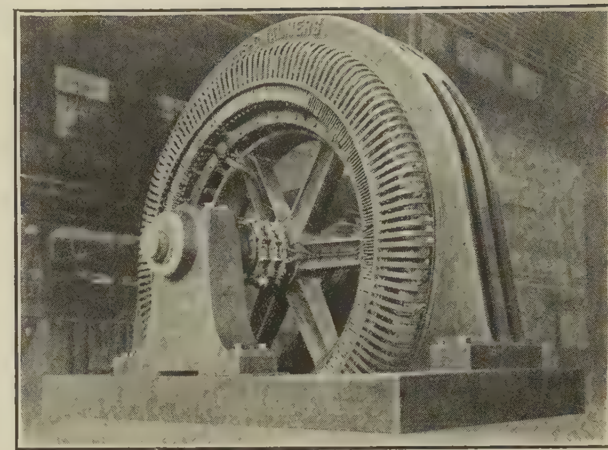


Fig. 27—1500-Hp. 163 1/3-Rev. per Min. Synchronous Motor for Use in Cement Mill

This motor has a distributed rotor winding as in an induction motor and starts in this way with high values of torque

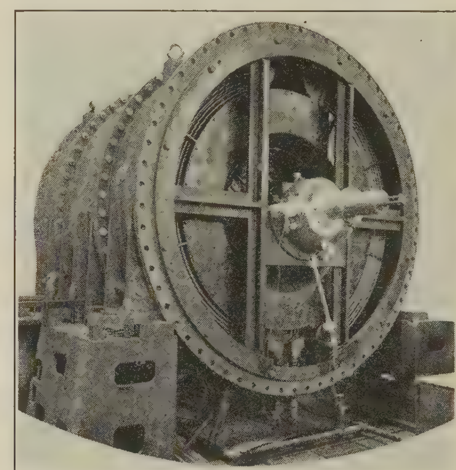


Fig. 28—Hydrogen Cooled Synchronous Condenser with End Bell Removed

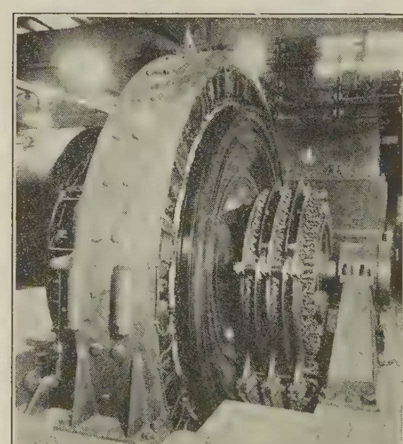


Fig. 32—4200-Kw., 25-Cycle Synchronous Converter Using Bent Slab Frame and Roller Bearings

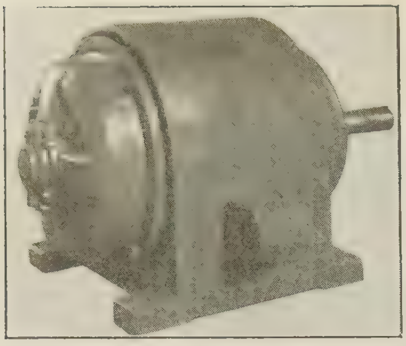


FIG. 33—ENCLOSED VENTILATED BALL-BEARING INDUCTION MOTOR

A new type of induction motor for use on very dirty applications where the rating is too large for totally enclosed motors

FIG. 40—ELEVATOR MOTOR IN WHICH EVERY PART IS WELDED EXCEPT THE ROPE SHEAVE

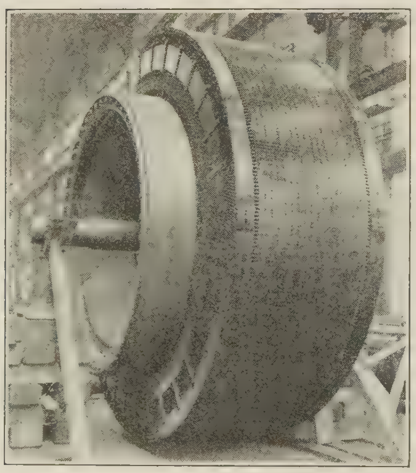


FIG. 37—ARMATURE FOR 7000-HP. REVERSING MOTOR SHOWING INVOLUTE EQUALIZER CONNECTIONS

Used in place of commutator necks for improving commutation

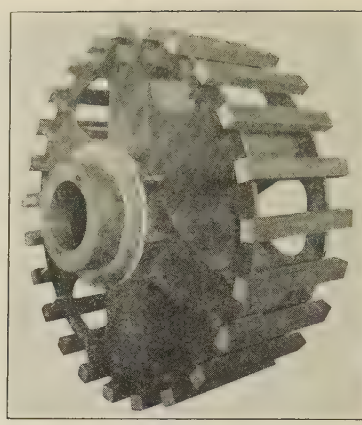


FIG. 39—ARMATURE SPIDER FABRICATED BY WELDING

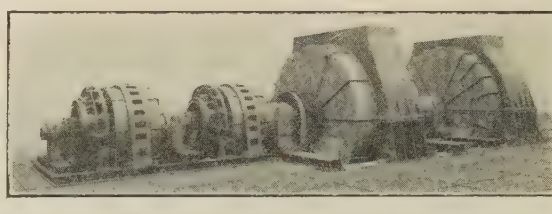


FIG. 36—SHOP VIEW OF 20,000-KW. ADJUSTABLE RATIO FREQUENCY CHANGER SET, 25/60 CYCLES

The induction motor on this set, rated 28,000 hp., is the largest rating yet built

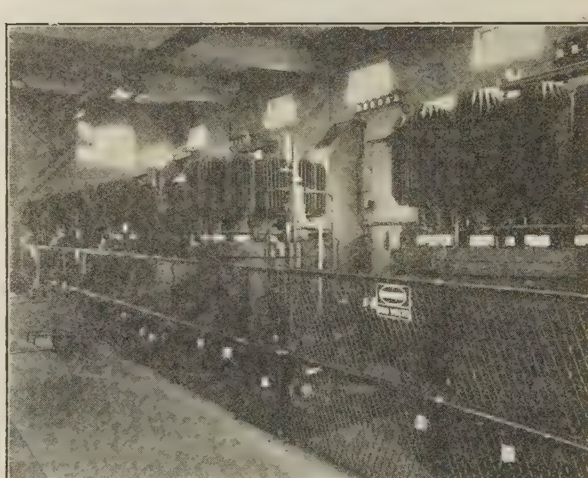


FIG. 41—FIVE 1200-KW. MERCURY ARC RECTIFIERS AT BRIDGEPORT, CONN.

The largest single installation in U. S. A.

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Abridgment of

Improvements in Moderate Capacity Oil Circuit Breakers

BY J. B. MacNEILL[1]

Associate, A. I. E. E.

***Synopsis.**—The increased duty requirements of power station service require circuit-breaker design to give maximum interrupting capacity in a minimum of space. Compact, relatively high-power breakers, having all three poles in a single round tank, have been designed. In addition to increasing the rating for a stipulated space, these give improved performance over types previously available. The relations of the current-carrying loops inside the breaker and the diversity factor afforded by the common oil volume and air space give superior results in operation. This type of design permits use in current ranges where decreased arc energy, as compared to power handled, can be secured.*

* * * * *

THE desirability of getting increased circuit-breaking capacity in a given space arises frequently in rapidly growing power systems. There have been many cases where the oil circuit breaker has been the "neck of the bottle" in limiting power that can be handled on a switch house layout. The bus itself, disconnecting switches and other elements, may be entirely adequate to handle increased power, but the circuit breaker may present severe limitations.

It is only natural that operators and manufacturers

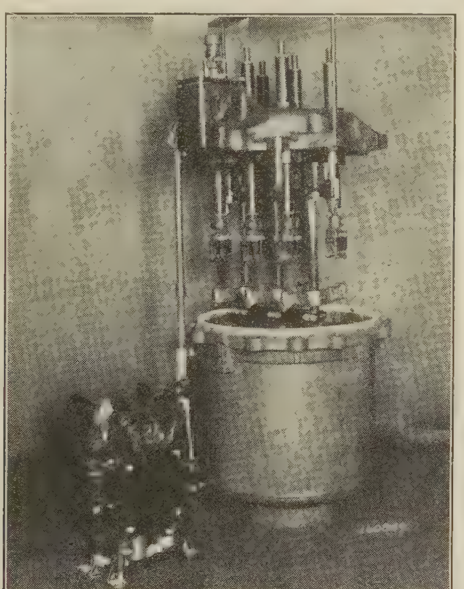

FIG. 1—THREE-POLE BREAKER IN SINGLE ROUND TANK SHOWING CONDENSER TERMINALS, CONTACTS IN OPEN POSITION, TANK REMOVED, AND ELECTRIC OPERATING MECHANISM

alike should be interested in the development of an oil circuit breaker to handle a maximum power in a minimum of space. To do this, it is obvious that the combination of a three-pole breaker in a single round tank should receive consideration because of the possibilities of embodying in such a type, the features that are used on high-power multiple breakers. A round tank is not in itself essential; in fact, any tank giving proper clearances and strength is sufficient. However, the

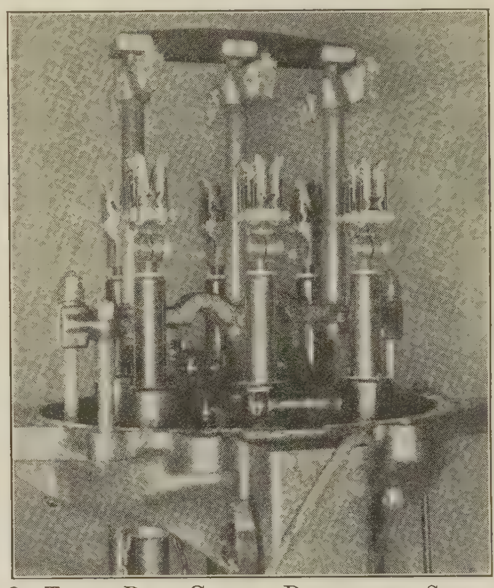

FIG. 2—THREE-POLE CIRCUIT BREAKER IN SINGLE ROUND TANK SHOWING CONTACT AND CROSS-BAR CONSTRUCTION WITH TANK REMOVED

ease with which necessary strength with minimum material can be obtained in a round tank with a dish bottom and a dome-shape cover, will be obvious.

In the past, objections have been raised in this country to the idea of multiphase switching in a single tank where considerable power is used. Many operators preferred isolation of the pole units from each other in separate cells so that in case of failure of one pole, fire and oil throw would have less chance to involve other phases. There was also the thought that when several phases were handled in a common volume of oil, the chances for arcs getting together would be increased. Therefore, manufacturers have not found it generally desirable to depart from the conventional mutiple single-pole arrangement for high-power work, because by so doing, they would have to handle two types whereas one would do the work.

1. Electrical Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Presented at the Regional Meeting of the A. I. E. E., St. Louis, Mo., March 7-9, 1928. Complete copies upon request.

Recently, however, there has been an increasing number of stations in which space is at a premium, or where cell structures have already been built and are too small to allow ordinary breakers to handle present power demands. Also, there has been a demand in the smaller capacities for breakers that throw minimum amounts of oil and gas, and where the outlet of the breaker can be piped away from the structure with assurance that such oil and gas will not be released in the cell structure itself.

The breaker shown in Figs. 1 and 2 was designed in 1922 to take care of the type of service referred to. It is a 20-in. diameter, round tank, three-pole breaker, embodying in a small space the general features of high-power breaker construction. The tank structure has a high ultimate strength, resulting from steel constructure throughout. It is equipped with a muffling device to separate the oil from the gas as it leaves the tank structure, and is so arranged that the gas can be piped away, thus preventing the possibility of gas explosions in the switch cell.

After extensive factory and field tests on the 20-in. tank size, the type of design shown in Figs. 1 and 2, gave promise of extension to other capacities, and a line of circuit breakers, comprising four tank sizes, are shown in Fig. 3, with ratings as follows:

Inside diameter of tank	Amperes at rated voltage	Approximate arc kv-a.
16 in.	7,500 at 7,500 volts	100,000
20 "	5,000 at 15,000 "	130,000
26 "	8,000 at 15,000 "	200,000
32 "	14,000 at 15,000 "	350,000

The performance of a breaker depends upon two principal factors; the first, the amount of energy released in the structure when opening short circuits, which may be called the energy or duty factor; and

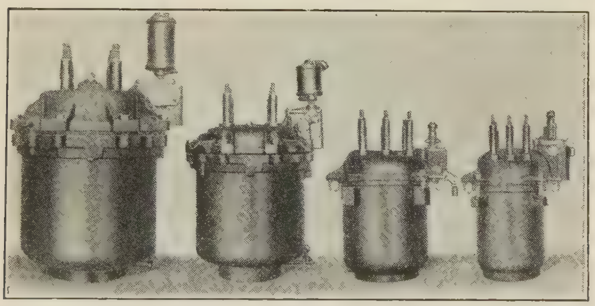

Fig. 3—Four Sizes of Three-Pole Single-Throw Oil Circuit Breakers Having All Poles in Single Cylindrical Tank

the second, the ability of the structure provided to take care of this energy after it has been formed, and which might be called the structure factor. The energy factor is represented by the integrated kilowatt-seconds obtained from the short-circuit current oscillograph record and the arc-voltage oscillograph record. The relationship of arc energy to short circuit kv-a. varies greatly with different designs of circuit breaker and also with different conditions of operation on the same circuit breaker structure.

A high-voltage circuit breaker handling small currents on short circuits has an entirely different ratio of arc energy to short circuit kv-a. than that of a low-voltage breaker handling high currents on short circuits.

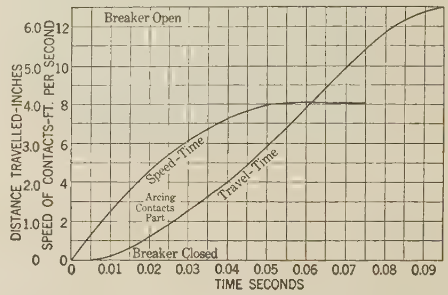

Fig. 4—Speed of Travel Curves of Three-Pole Single-Throw Breaker in One Round Tank

Likewise, a breaker designed for, say, 15,000 volts, will have a different ratio when operated at 2500 volts. A knowledge of the variations of arc energy with short circuit kv-a. is necessary to the successful design of a line of circuit breakers. This is especially so because facilities for testing the largest breakers do not exist, and their design depends on extrapolating results obtained on smaller sizes.

Figs. 5 to 13, inclusive, show various operating characteristics of the multiple breaker in a common round tank when opening three-phase short circuits on a 60-cycle, ungrounded neutral system.

In Fig. 5 is shown the relationship between short-

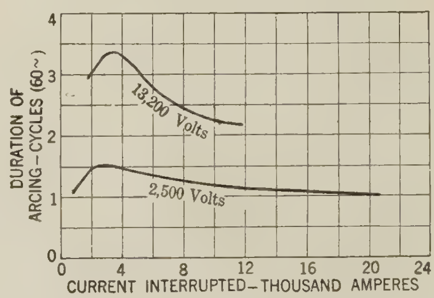

Fig. 5—Curves Showing Duration of Arcing with Current Interrupted at Different Voltages

circuit amperes and cycles of arcing at 13,200 volts and 2500 volts for a given breaker structure of the type under discussion. This is simply a curve of averages and is subject to considerable variation between successive short circuits. It serves, however, to indicate the general relationship between duration of an arc and the amount of current in the arc. The shape of this curve is affected by the speed of the parting of contacts, the number of breakers in series per phase, the magnetic blowout effect of the current-carrying loop, the spacing between the arcing contacts and the tank liners, and to some extent on the head of oil over the contacts and the

volume of the air-chamber. From the point of view of the system connected to the breaker, the shape of this curve depends on the restored voltage, whether the neutral is grounded at the short circuit as well as at the machine, the power factor during the short circuit, and other considerations.

It has been found, however, that for 15,000 volts (and below, especially) curves of the general shape shown in Fig. 5 are secured under different conditions of system and breaker characteristics.

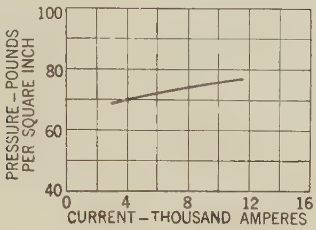

Fig. 6—Tank Pressure Variation with Current Interrupted on Three-Phase, 60-Cycle, 13,200-Volt Ungrounded Short Circuits. Three-Pole Breaker in One Round Tank

In Fig. 5 it is noticeable that the time of arcing for large currents is less than that with relatively small currents. The arcing time increases for a while with current, but there comes a point where this time begins to diminish rapidly, and finally the curve becomes practically asymptotic. The position of the high part of this curve depends on the magnetic blowout action on the arcs. The type of breaker shown keeps the high point of the curve at lower current values than do some other types, because the current-carrying loops are closer together, and the magnetic blowout effects are in general greater. It will be obvious that a lower time of arcing at high currents results in a reduction in the arc energy dissipated in the breaker and resulting oil throw, contact depreciation, and stresses which the structure has to withstand.

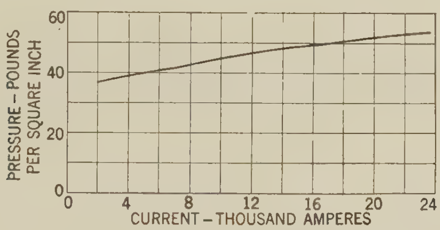

Fig. 7—Curve Similar to that in Fig. 6, for 2500-Volt Service

Curves in Fig. 13, showing single-phase arc energy as a function of current interrupted, are of interest. For the particular case, the arc energy varies almost directly as the short-circuit current, but differs greatly for the different voltage classes. This is readily seen from the differences in arcing times shown in Fig. 5.

An interesting relationship is that between kilowatt-seconds dissipated in a breaker and the kv-a. of the short circuit interrupted by it. From Fig. 13, we find that for 13,200 volts, the three-phase kilowatt-seconds of arc energy is 0.0035 of the three-phase short-circuit kv-a. As an illustration; at 6000 amperes, the arc energy for 13,200 volts is 160 kilowatt-seconds per phase.

$$\text{The relation } \frac{\text{arc energy in kilowatt-seconds}}{\text{kv-a. interrupted}} =$$

$$\frac{3 \times 160}{13.2 \times 6000 \times \sqrt{3}} = 0.0035$$

In the same way, for 2500 volts, the ratio is 0.0049.

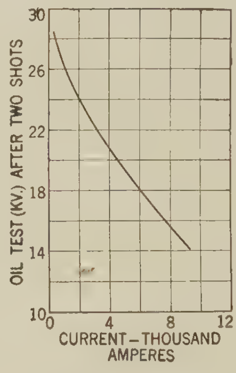

Fig. 8—Oil Test—Three-Pole Breaker in One Round Tank after Opening Three-Phase, 60-Cycle, 13,200-Volt Ungrounded Short Circuits

Accordingly, there is more energy lost per kv-a. in a breaker of this particular design on low voltage, such as 2500 volts, than on 13,200 volts. With other designs of breaker, this relationship may not hold, and the factors of arc energy related to kv-a. in the short circuit may be quite different.

Several articles have been written on this general matter, and it is interesting to note comparable results. In the *Gen. Elec. Rev.*, May 14, 1921, P. Charpentier developed a formula for arc energy in terms of circuit voltage, short-circuit current, and time of arcing, in which he assumed that the time of arcing varied directly with voltage for a given velocity of contacts. According to Charpentier's formula, a breaker of this design, opening 6000 amperes, three phases on a 13,200-volt circuit, would have a factor of 0.0031 as the relationship between arc energy and short-circuit kv-a. This is in close agreement with the similar factor derived from the data here presented.

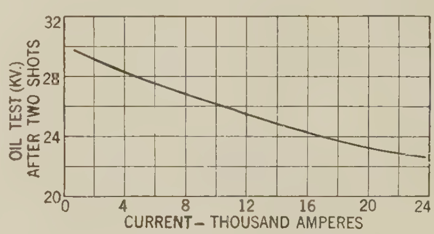

Fig. 9—Curve Similar to Fig. 8, Except for 2500-Volt Circuits

However, for short circuits of similar kv-a. on lower voltages, this agreement does not hold. The average ratio for 2500-volt circuits (taken from data on Fig. 13) is 0.0049, while Charpentier's formula would give a ratio of 0.0006. This wide discrepancy is accounted

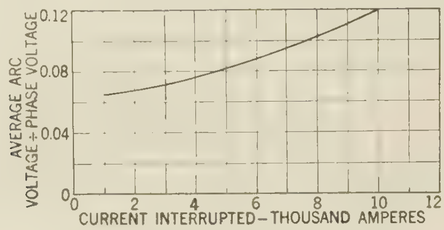

Fig. 10—Variation of Average Arc Voltage to Phase Voltage Ratio with Respect to Current Interrupted, 13,200-Volt, 60-Cycle Ungrounded Circuits

for by the fact that arc energy as shown in Fig. 13 is rather directly a function for this particular breaker of short-circuit currents, and arc voltage at the high currents secured with low-voltage short circuits is a considerably greater proportion of line voltage than it is for higher voltage circuits. This is borne out by Figs. 10 and 11. From Fig. 10 we find that for 13,200 volts, the average arc voltage at 6000 amperes is approximately 8 to 9 per cent of phase voltage, whereas for similar kv-a. at 2500 volts the average arc voltage is approximately 25 to 30 per cent, as indicated by Fig. 11.

In the development of the line of breakers shown in Fig. 2, an unusual amount of short-circuit testing has been possible. In 1923 the Detroit Edison Company cooperated in the development and testing of the 20-in.

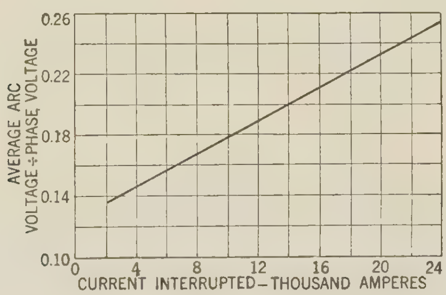

Fig. 11—Curve Similar to Fig. 10, Except for 2500-Volt Circuits

tank size. At their DelRay Station currents as high as 25,000 amperes at 4800 volts were handled successfully, and with much less signs of stress on the structure than on conventional forms of breakers of larger physical size. Afterward a 40,000-kv-a., 10 per cent reactance factory test plant became available, and exhaustive series of tests have been made.

There are certain diversity factors about this type of breaker that will interest an operating man. The oil volume and air volume are common to the three poles. Since by far the greater number of short circuits are single phase, the total oil volume will not depreciate as fast as though the single-phase short circuit had been on one-third of the oil, which would be the case with a multipole breaker having separate tanks. Also, the common air volume tends to diminish the shock to the breaker structure that occurs on single-phase short circuits, so that while the maximum pressure to which

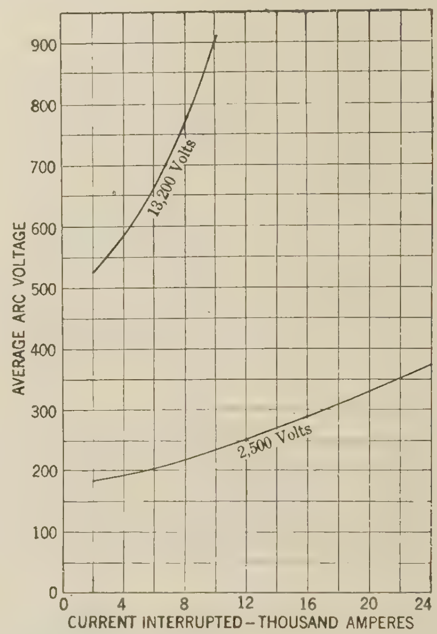

Fig. 12—Relation of Average Arc Voltage to Current Interrupted for Three-Phase, 60-Cycle Ungrounded Short Circuits. Three-Pole Breaker in One Round Tank

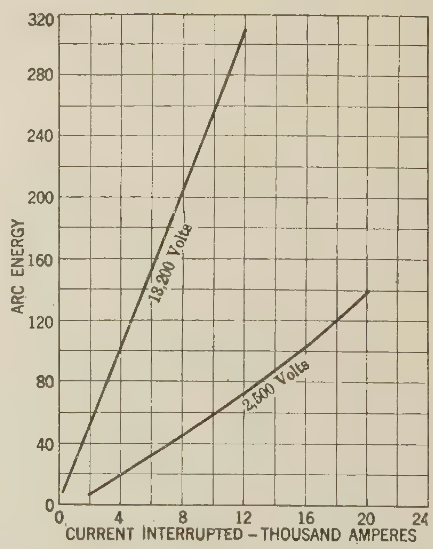

Fig. 13—Relation of Arc Energy per Phase to Current Interrupted on 60-Cycle Ungrounded Circuits. Three-Pole Breaker in One Round Tank

the breaker may be subjected may be considerable, the average pressure under operating conditions will be reduced. In general, it is felt that less maintenance for a given duty will be obtained with this form of breaker than with a multiple single-pole breaker, and also that the maintenance is more easily and quickly performed.

Abridgment of

Problems in Power-Line Carrier Telephony
And Recent Developments to Meet Them

BY W. B. WOLFE* and J. D. SARROS*

Member, A. I. E. E. Non-member

Introduction

POWER-LINE carrier telephone systems have been in operation in this country for the past six years. This form of communication may be used either as a primary means of telephone service for the transaction of dispatching and other business, or it may be employed chiefly as an emergency service to supplement facilities the power company already has at its disposal.

To date, several types of equipment have been designed to meet these needs. However, the growing complexity of power systems, involving a higher standard and more comprehensive communication service, indicates the desirability for a better type of carrier circuits and equipment. The purpose of this paper is to outline in general the difficulties to be met in applying high-frequency communication to power systems, and to describe a recent development in equipment for this class of service.

The Problem

The problem of providing high-frequency communication over power circuits must be considered first from the angle of the general purpose of this type of communication. Formerly, power-line carrier telephone circuits were considered primarily as channels for load dispatching business. While the primary use is for load dispatching work, there is also considerable demand for such circuits to be used for general business transactions. For load dispatching service only, the circuit may be an isolated one, providing communication from the dispatcher to one or more generating or substations, but, this may not meet load dispatching requirements and is rarely satisfactory for general business. It therefore becomes desirable to make the carrier circuit a coordinated part of the entire communication system of the power company.

Considering the general circuit requirements, we find that these in general have not changed. Stable, reliable circuits of good quality, and with low noise, have been required from the start. One factor which perhaps has increased in importance is the requirement that the equipment itself be designed for sufficient flexibility to permit of adapting it to all the different conditions encountered on power circuits. Another factor which while not previously overlooked has risen to considerable prominence recently, is the necessity for multiple-channel operation on any given power circuit without interference between channels.

Character of the Transmission Medium Presented By a Power Network

In designing apparatus to provide communication service, the most important consideration is the character of the transmission medium to be employed for the communication channel.

Earlier investigations[1] showed the superiority of a full metallic circuit over a ground return circuit from standpoints of both attenuation and stability as well as noise. Over the range from 50 to 150 kilocycle the attenuation of the power line without branch lines or connected apparatus has been found to be of the order of 0.05 to 0.1 T U per mi.[2] This loss is very low and indicates the possibility of securing excellent communication under such conditions. Unfortunately, power circuits are not ordinarily simple straightforward circuits but involve branch lines, closed loops, and other irregularities which radically change their character as a transmission medium.

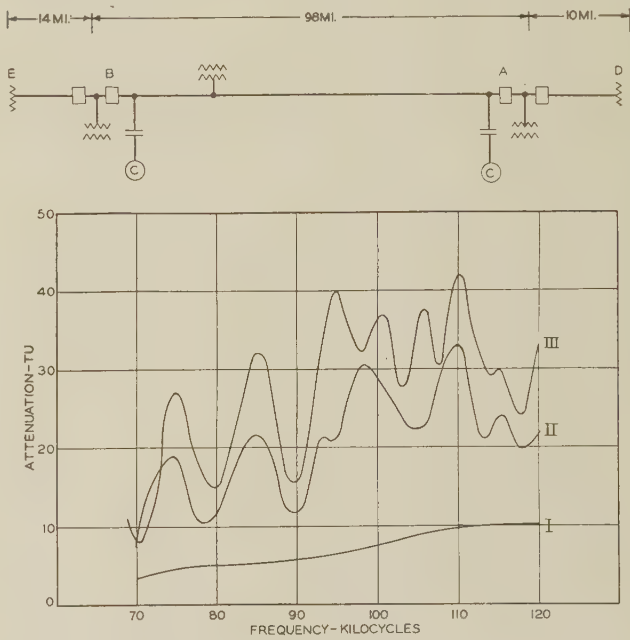

Fig. 1—Effect of Line Switching on the Attenuation Characteristic.

There is shown on Fig. 1 a power network involving a 110-kv. line with carrier terminals located at A and B a distance of about 98 mi. Curve I gives the character-

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Presented at the Pacific Coast Convention of the A. I. E. E., Spokane, Wash., Aug. 28-31, 1928. Complete copies upon request.

1. For references see Bibliography.

istic of the line $A\ B$, which, for this test, was, entirely isolated from the system except for a transformer bank 23 mi. from B. Curve II shows the characteristic of the same line with the 14-mi. circuit $B\ E$ and its associated equipment connected. It is evident that the introduction of this circuit not only increases the average attenuation of the line $A\ B$ but also introduces serious irregularities caused by reflection and absorption effects. Thus, in a 5000-cycle interval, under this condition, there is as much as 10 T U variation in attenuation. Curve III shows the characteristic of this same section $A\ B$ with both $B\ E$ and a 10-mi. branch $A\ D$ with its associated equipment connected in at the other end. Again we have an increase in average attenuation. The irregularities due to reflections are now so pronounced that they give a 20-T U variation in attenuation over a 5000-cycle interval. There may be no similarity between the last two conditions; that is, the peaks and troughs in attenuation may not occur at the same frequencies. We not only have *irregularity* in the high-frequency characteristics but *instability* as well. Thus, a carrier-frequency band, which may have been selected as the result of considerable effort and which may be very satisfactory for a given condition, is often rendered absolutely useless by a change in the line conditions.

A knowledge of the noise conditions likely to be encountered on power networks is likewise necessary for the correct design of the carrier terminal equipment, but unfortunately the factors involved here are many and of varied character. Among these sources of high-frequency noise may be mentioned corona and leaky insulators. The latter trouble may be due to faults in the insulators or to collection of dust or other foreign material on the insulators. A prolific source of noise has been found in the spitting or arcing which occurs between the power conductor and metal objects close to the conductor but not connected to it.

The presence of corona on a power circuit introduces a very interesting possibility from the standpoint of noise production. Effective conductor variations, occurring as indicated by Doctor H. J. Ryan, would cause the attenuation of the power circuit to vary and thereby produce modulation on the line itself. If such is the case, the amount of noise observed in the voice frequency range would increase directly as the transmitter power in the carrier circuit was increased.

From these observations it is evident that the successful operation of carrier communication over power lines does not depend alone on the development of the carrier apparatus. The transmission line is a very important link in the system and can vitiate the performance of otherwise perfect equipment.

Fundamental Circuit Considerations

We may now consider the fundamental types of circuits available for high-frequency communication on power lines.

Full duplex operation can be obtained by using two independent pairs of wires, or circuits,—one circuit for transmission in each direction. This method is highly satisfactory, but in this case it is uneconomical since it requires two independent circuits for a given conversation. To obtain duplex or automatic two-way operation when one circuit is used for both transmission and reception, means must be provided for separating the transmitted and received currents. This is generally done by using any one or a combination of three general methods:

1. Frequency separation.
2. Balance or bridge method of separation.
3. Use of voice controlled relay circuits.

Frequency separation involves the use of two frequencies, one for transmitting in each direction. Selection between the two is obtained by the use of selective circuits or filters.

Separation by the use of balance or bridge methods is extensively used in the communication art where the lines are electrically long and their impedances remain substantially constant. So long as the bridge standard, or network, matches the impedance of the line at each frequency used, no energy will be transferred from transmitter to receiver.

An automatic two-way circuit which in its operation is essentially a duplex circuit may be secured by the use of voice controlled relay circuits. These circuits may employ mechanical relays or vacuum-tube circuits for their operation. In either event, the transmitting circuit is rendered inoperative during the receiving interval, and, conversely, the receiving circuit is inoperative during the transmitting interval.

Perhaps the most important consideration is the type of high-frequency transmission to be employed. There are three systems commonly used:

1. Systems transmitting the carrier and both side-bands.
2. Systems transmitting the carrier and one side-band.
3. Systems transmitting one side-band only.

When two frequencies, such as a speech frequency and a carrier frequency, are properly introduced into the ordinary vacuum-tube modulator, the products of modulation consist of the sum and difference of these two frequencies, called, respectively, the upper and lower side-band, and the carrier frequency, besides other modulation products which may be neglected in this discussion. These side-bands are symmetrical in position with respect to the carrier frequency and each side-band by itself contains all the elements necessary to transmit the original speech.

Obviously, therefore, it is not necessary to transmit both side-bands with the carrier, since the original voice frequencies may be faithfully reproduced by demodulation between the carrier and either the upper or the lower side-band. Furthermore, the carrier is a constant frequency whose amplitude need not vary with the

amplitude of the voice. The carrier may be suppressed at the transmitting terminal after modulation has taken place, and be re-introduced at the receiving terminal for demodulation.

The system transmitting the carrier and both side-bands is that employed for broadcasting, and prior to this time for all power-line carrier telephone circuits. This type of system requires a frequency band of approximately 5000 cyles in width for the transmission of speech having reasonably good quality.

A system transmitting the carrier and one side-band has essentially the same features as that transmitting the carrier and both side-bands except that the band width may be reduced to approximately 2500 cycles for the same quality.

The third system in which the side-band alone is transmitted requires supplying the carrier locally to the receiving circuit. For comparable quality this system also employs a frequency band of 2500 cycles.

Characteristics of the New Power-Line Carrier Telephone System

From consideration of the service requirements, the line characteristics, and the circuits available, a single frequency, single side-band, carrier-suppressed system has been adopted as the most efficient and reliable means of getting satisfactory communication over power circuits.

Its advantages over a two-frequency system are as follows:

1. It is less likely to be affected by the irregularities and instability of power-line high-frequency characteristics.
2. Transmission loss in each direction is the same.
3. Party line conversation is practicable.

Carrier suppression and the use of a single side-band give it the following additional advantages.

4. It is more easily adaptable to single-frequency operation.
5. It gives better quality through irregular line characteristics.
6. Ordinary line noise and noise due to any line modulation is more effectively subordinated.
7. Frequency conservation makes multi-channel operation easier.
8. Received speech level is less affected by line attenuation changes.
9. It has a greater transmitting range for the same power.
10. Lower transmission loss and greater selectivity secured in coupling to power line.

The question of the irregularity and instability of the line attenuation characteristic and its effect on the operation of any system has already been mentioned Although the use of the same band of frequencies for transmission and reception simplifies the problem, this advantage is enhanced by the use of a single side-band system since the required frequency band is a minimum. This is a distinct advantage because cases have been met where the peaks in the frequency spectrum were extremely sharp and only one frequency band offered good operation under all line conditions.

It is obvious that the transmission in each direction with any single-frequency system is the same.

Party line conversations are not practicable with a two-frequency system, although it permits "broadcasting" instructions to all terminals on the line. With a single-frequency system, instructions may be issued to all operators simultaneously, and a general discussion may be carried on between terminals.

Single side-band transmission simplifies the problem of obtaining automatic two-way operation by the use of voice-operated vacuum-tube relay circuits, since there is no output from the transmitter so long as there is no input into the microphone.

Single side-band transmission gives better quality through irregular line characteristics by virtue of the fact that the band width is narrow.

It is apparent that a system with such a high degree of selectivity will be less sensitive to interference either from line noises or from other carrier channels. Conversely, since a very narrow band is transmitted, the possibility of it interfering with other systems or channels is reduced to a minimum. There is the added advantage that interference from noise as a result of possible line modulation is reduced.

Since, in single side-band transmission, the frequency band is only half as wide as is required with double side-band transmission, the conservation of frequency spectrum resulting thereby facilitates multi-channel operation.

The amplitude of the received signal is a function of the amplitudes of the carrier frequency and of the side-band frequency. For a carrier-transmitted system, the amplitude of the received speech may vary at a greater rate than the changes in the transmission loss, since the amplitudes of both carrier and the side-band are correspondingly varied. For a carrier-suppressed system, the amplitude of the received speech changes in the same ratio as the transmission loss, since only the amplitude of the side-band is affected and the amplitude of the locally supplied carrier remains constant.

For ordinary modulation, we can say that 100 watts of single side-band energy is approximately equivalent to 500 watts where the carrier and both side-bands are transmitted.

The fact that a narrow band is transmitted makes possible the use of relatively low capacity coupling condensers and consequently a coupling filter of high efficiency and maximum selectivity can be designed. Additional selectivity through filters is provided at the input of the first demodulator, between the first and second demodulator, and at the output of the latter.

Description of Circuits

At the risk of repeating much that has already been written[4] we shall now discuss in general the fundamental principles underlying the operation of this new power-

line carrier telephone equipment. The satisfactory performance of a single side-band carrier suppressed system depends to a great extent on the solution of the following problems:

1. The sufficient suppression of the carrier at the transmitting end.
2. The elimination of the undesired side-band.
3. The design of high stability oscillators.

synchronism cannot be realized in practise, and measures are taken for suppressing to the desired degree the carrier and unwanted side-band in order to circumvent the slight discrepancy between the modulating and demodulating carriers. Balanced, or push-pull modulators, as employed here, suppress the carrier to a considerable extent. Further attenuation is obtained by locating the frequency of the carrier at a point beyond

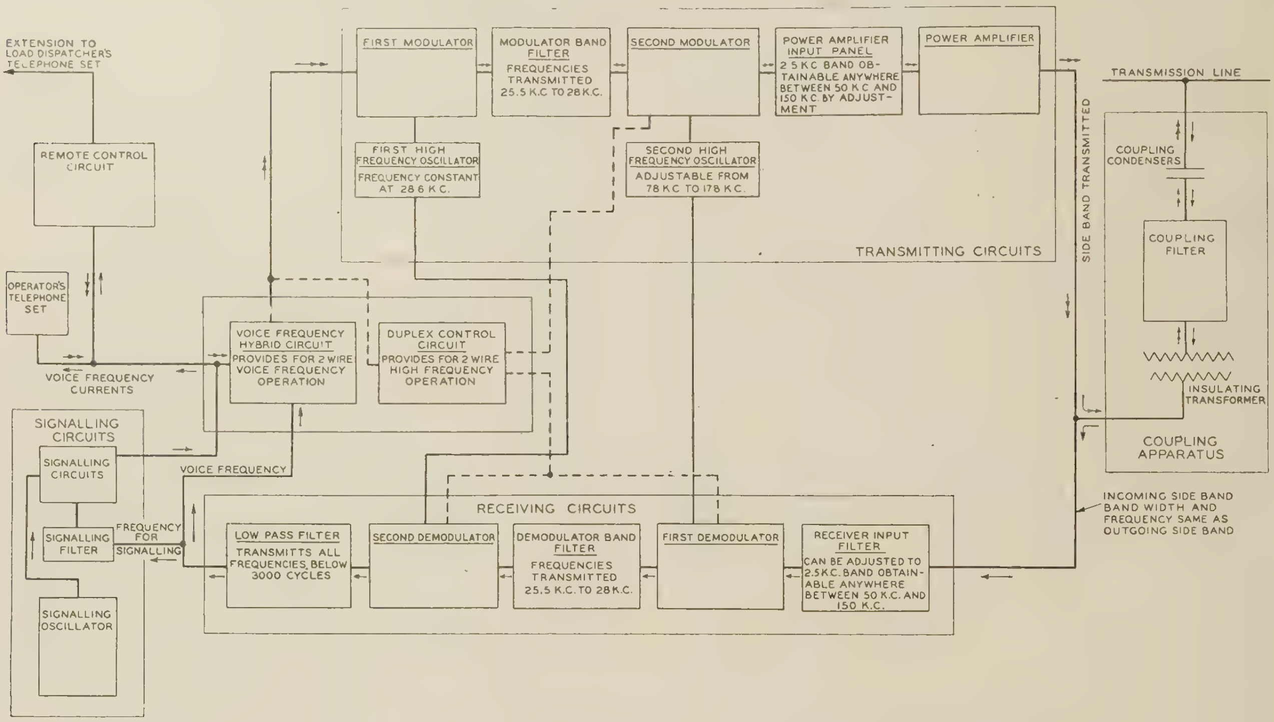

Fig. 2—Block Schematic of Single-Frequency Duplex Power-Line Carrier Telephone System Employing Single Side-Band Suppressed Carrier Transmission

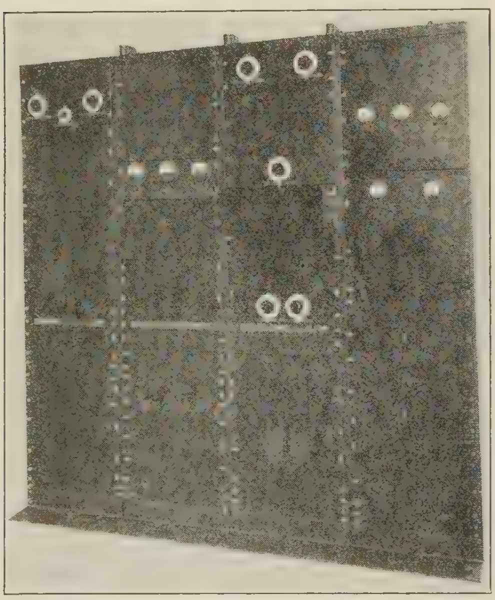

Fig. 3—Front View of Equipment

The oscillators used to supply high frequency for modulation and demodulation are of extremely high stability and have proved very satisfactory. However,

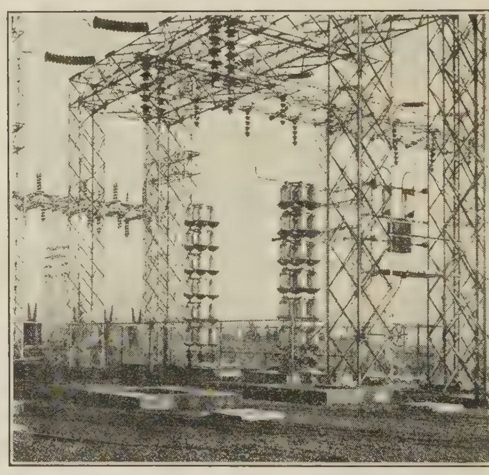

Fig. 5—220-Kv. Coupling Condensers

the cut-off of the attenuation characteristic of the band pass filter used for eliminating the undesired side-band. Any carrier that may be transmitted under these conditions is further prevented from causing trouble by the use of balanced demodulators.

Another interesting phase in connection with this problem is the use of double modulation and demodula-

tion. Double modulation provides a convenient and simple means for obtaining the advantages of a single sideband suppressed-carrier system at power-line carrier telephone frequencies. With double demodulation as employed here, the same carrier frequencies are used for both modulation and demodulation.

In the case of the system under consideration, duplex or automatic two-way operation is obtained by the use of voice-operated vacuum-tube "relay circuits." This is effected by rendering either the transmitter or receiver inoperative by causing the voice itself to control a heavy negative grid bias on the modulator and demodulator tubes. There is also provided an interlocking device which prevents incoming energy or room noise from rendering the transmitting circuit operative while receiving. Essentially this same scheme is employed in the transatlantic radio circuit.[5] It has also been in use for years in long cable toll circuits where echo suppressors[6] have been found to be indispensable.

All power for plate and grid potentials is derived from vacuum-tube rectifiers. The filaments for the low-power tubes may be supplied from a 30-volt storage battery.

Initial Installation

Three terminals of this new equipment are now in operation on the lines of the Pacific Gas & Electric Company. They have provided a communication service over power circuits which have presented very serious communication difficulties to apparatus previously tried. The high-tension circuit over which this equipment operates, consists of the 202-mi., 220-kv. lines from Pit No. 1 Power House to Vaca Dixon Substation and of the 58-mi., 110-kv. lines from this point to the Claremont Substation in Berkeley. From Claremont to the load dispatcher in Oakland, there is a five-mile two-wire low frequency extension of underground cable with remote control at the dispatcher's office. The voice-frequency circuit may be extended from the dispatcher's office or any of the carrier terminals by connection to other two-wire telephone circuits.

There are three points of particular interest in this installation. First, the 58-mi. section is part of one of the largest 110-kv. networks in the country and potentially, therefore, subject to wide changes in its high-frequency characteristics. Second, the transfer of the high-frequency energy from the 110-kv. line to the 220-kv. line (and vice versa) is accomplished through a by-pass or filter circuit without the use of a repeater. Third, this particular 220-kv. line presents an unusually difficult problem because of the large amount of high-frequency noise present. This noise is probably produced from two major sources—corona and static discharges between the line conductors and the corona shields.

Conclusion

The terminal equipment described in the foregoing discussion represents a distinct advance and employs the circuits and apparatus best suited for our present conception of the service requirements and our present knowledge of power-line conditions at carrier frequencies. It must be remembered, however, that power lines as at present constructed and operated present an uncertain medium for communication, and that although this equipment overcomes these difficulties to a large extent, the effectiveness of power-line carrier telephony would be considerably increased by an improvement in the transmission medium.

Some work has been done on methods for stabilizing power-line conditions at high frequencies, but so far, the results have been meager and the apparatus developed has not met with general approval. Considerable work remains to be done on this problem. Its satisfactory solution will materially increase the effectiveness of power-line carrier telephone circuits. These improvements, of course, will in no way detract from the superiority of the single-frequency, single side-band carrier-suppressed system therein described.

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CANADA'S ELECTRICAL GROWTH

Recent statistics on power consumption in Canada show that the average number of kilowatt-hours of electrical energy generated daily for Canadian use, exclusive of energy exported, during the month of May was 37,000,000, as compared with 31,000,000 in May, 1927, and 25,000,000 during the same month in 1926. The amount generated in May, 1923, was 16,000,000 kw-hr.

Since 1923 Canadian production has increased by 129 per cent, and, using the amount generated in 1923 as a base, the yearly increase during the past five years has amounted to more than 25 per cent. This large increase in Canadian power production has taken place during the period when there was an extraordinary development going on in the newsprint industry. In 1923 newsprint production during the first six months of the year amounted to 627,000 tons, and in 1928 the total for the corresponding months was 1,164,000 tons.

Mercury Arc Rectifier Substations

BY GEORGE E. WOOD[1]

Non-member

Synopsis.—Mercury arc rectifiers alone supply the power for the electric railway system at Bridgeport, Connecticut. In this paper are given an account of the rectifier substations and some reports of the operating experience during the last several months since the stations were completed.

* * * * *

"FROM obsolescence to modernity" within a period of less than a year is the story of the rehabilitation of the power facilities of the Bridgeport Division of The Connecticut Company. The intent of this paper is to present a brief yet comprehensive description of the new substations recently completed. Also to set forth such operating data as have been gathered during the short period they have been in operation.

During the autumn of the year 1926 it was decided to abandon the old steam generating station on Seaview Avenue on account of steadily increasing production costs resulting from obsolete types of equipment and physical depreciation. In analyzing the situation, not only was the type of equipment considered, but also possible improvement in the distribution system, and all phases relating to economical power costs.

Preliminary studies disclosed the fact that the mercury arc power rectifier had several advantages over the synchronous converter and the motor-generator set which, from the standpoint of economy, demanded serious considerations. However, on account of its comparatively recent advent into the American field of converting equipment of medium and large capacities, its one great disadvantage was that little was known of its reliability.

Had the contemplated improvements been simply the installation of an addition to the present facilities, there would have been no hesitancy in choosing the rectifier. But such was not the case. The company was confronted with a problem involving the renewal of its entire facilities having in mind economy and reliability as the major considerations. There were no prior installations in which the rectifier was employed as the sole means of powering a traction system in its entirety and consequently there were no established facts available for guidance.

Investigation of the rectifier disclosed the fact that wherever it was in service, it was functioning in a creditable manner. It was efficient and much more reliable than general opinion had credited it with being. Accordingly it was decided that, in the interest of economy, it should be installed in the new stations then under consideration. Actual work on the new stations commenced in March 1927.

The territory served by the substations, as well as the location of the old and new facilities, is shown in Fig. 1. The site of the old Seaview Avenue Steam Plant was abandoned and the substations erected on the sites indicated, in order that power might be delivered more nearly at the center of load. The outstanding advantages of the new locations are; better voltage conditions on the various car routes, an annual saving in power losses, the abandonment of a submarine cable crossing and its attendant hazards, the salvaging of approximately 30 mi. of feeder and the elimination of the necessity of expending $60,000 for a new submarine crossing, a condition brought about by the construction of a new bridge over Yellow Mill Pond.

Analysis of load conditions indicated that the station in Bridgeport required a capacity of 6000 kw. in order to carry its heaviest loads and still allow sufficient reserve. The capacity required of Stratford was 1600 kw. Tentative plans indicated that a 2000-ampere continuous rating rectifier with 12 anodes was most economical from the standpoint of building costs. Accordingly seven rectifiers were purchased, five for installation at Bridgeport and two at Stratford. The advantage gained on making all units identical in size and characteristics was considered sufficient to install a slightly greater capacity at Stratford than was required.

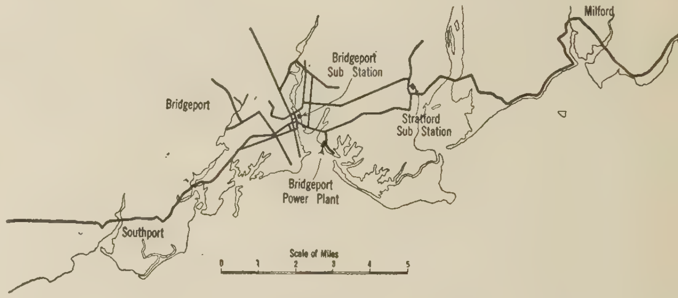

Fig. 1—Street Railway System Fed Only by Mercury Arc Rectifiers

As regards the capacity of the rectifiers, it may be said that they have two ratings. First, they are capable of delivering 2000 amperes at 600 volts continuously with momentary overload capacity of 3000 amperes. Second, they are capable of delivering 1500 amperes continuously, 2250 amperes for two hr. period and 3000 amperes momentarily.

Primary, three-phase, 60-cycle power at 13,900 volts is purchased from The New York, New Haven and Hartford Railroad Company at its substation adjacent to the Devon Plant of the Connecticut Light and Power Company approximately seven miles east of Bridgeport.

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Presented at the Northeastern District No. 1 Meeting of the A. I. E. E., New Haven, Conn., May 9-12, 1928.

This power is transmitted over two three-phase 4/0-stranded copper high-voltage lines which are strung on the towers on the north and south side of the railroad company's right-of-way. Both lines are normally energized, the so-called South Line being given preference in carrying the load. These transmission lines are connected to outdoor high-voltage structures at Stratford and Bridgeport through the usual switching equipment.

The essential difference between the two stations lies only in the fact that the Bridgeport station is arranged for manual control whereas the Stratford station is fully automatized. On account of this similarity a description will be given only of the Bridgeport Station.

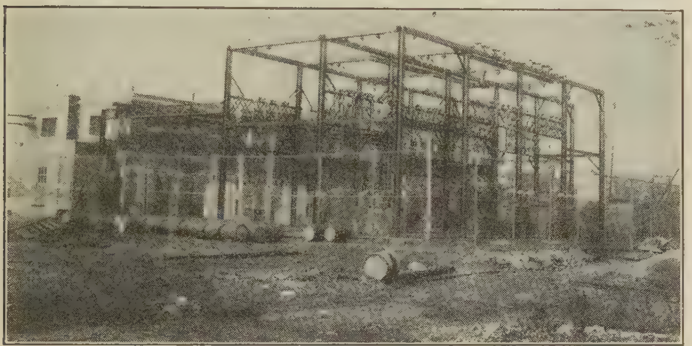

Fig. 2—Substation at Bridgeport

The design of the outdoor structure and the arrangement of equipment (Fig. 2) lends itself at once to simplicity, flexibility and reliability. The arrangement is symmetrical and provides such clearances between the various units as will afford the maximum of safety to the operators. The high-tension bus of copper tubing is suspended from the upper chords of the structure over the aisle between the incoming line oil circuit breakers and those controlling the individual rectifiers. This bus is sectionalized at a point between the incoming lines dividing the station, if desired, into two complete units of two and three rectifiers each.

A special feature of the bus layout is an auxiliary bus tapped from each of the incoming transmission lines ahead of their control breakers. These auxiliary buses occupy a position similar to the main bus over the aisle between the lightning arresters and the transmission line control breakers. They are both normally energized and are connected through auxiliary transformers to the 220-volt auxiliary bus within the station. In the event of failure on either transmission line, the station auxiliary bus is automatically transferred from the line upon which the failure occurs to the other by means of an automatic change-over switch. This arrangement was resorted to in order to insure a continuous supply of power to the auxiliary equipment so reducing the duration of outages to an absolute minimum in case of line trouble.

A third bus extends the entire length of the structure over the center line of the rectifier transformers. This is the station negative bus to which the neutral points of the transformers and aerial negative track returns are connected. The negative side of all instruments within the station are brought through a common lead to this bus and with this exception, the entire negative side of the system is out-of-doors.

All of the outdoor equipment is of standard design and manufacture, the oil circuit breakers controlling the incoming lines being Type FO-40-A, and those in the rectifier circuits, Type D-16-A. All breakers are arranged for 220-volt, three-phase motor closing and 24-volts d-c. tripping.

The current and potential transformers are of the oil immersed type.

The transformers are of the O. I. S. C. type and their arrangement is unusual in that it consists of a step-down transformer with an auto-transformer inserted in the line. This arrangement was resorted to in order to keep the main transformer dimensions within reasonable limits and to simplify its construction, as each transformer was required to be built for operation from either a 25- or 60-cycle, three-phase source of supply at primary voltages of 6600, 11,000 and 13,900 volts, with five 2 per cent taps above and five 2 per cent taps below normal voltages, the

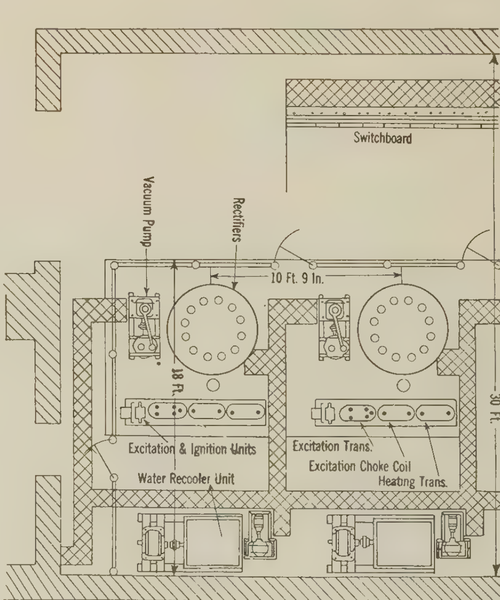

Fig. 3—Section of Mercury Arc Rectifier Substation

secondaries to be arranged for double six-phase, 550 volts and the neutral points to be brought out for connections to the negative bus. The function of the auto-transformer, therefore, is to provide the necessary taps to meet these requirements.

The transformers are all truck mounted and may be removed for repair by transferring to a low geared truck operating in the track shown in the plan.

The building is of simple, though substantial, construction and has a floor area of 0.29 sq. ft. per kw. of installed capacity. On account of its proximity to the

Poquonnock River it is erected on wooden piles and concrete sub-foundations. The sub-floor is waterproofed as are the side walls. Between this floor and the operating floor all conduits are installed. The conduit for the anode leads is bricked into the wall and extends to the pull box adjacent to the rectifiers. All wires between the switchboard and the rectifiers,

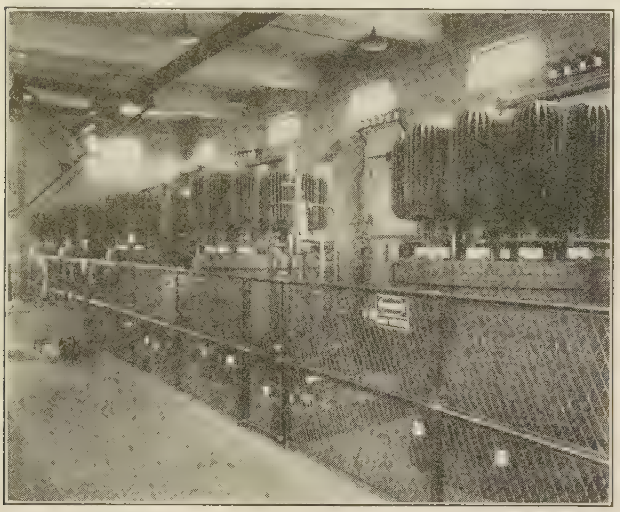

Fig. 4—Interior of Substation

auxiliaries, and control apparatus enter a trench in the rear of the switchboard thence to the apparatus.

The rectifiers, vacuum pumps, ignition and excitation transformers (Figs. 3, 4, and 5) are mounted on a raised platform extending the length of the station. They are enclosed by a screen four feet high as all external surfaces are alive when under load.

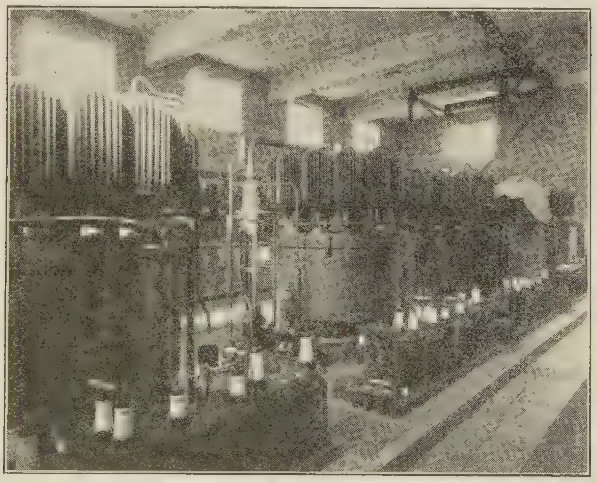

Fig. 5—View of Rectifiers, Vacuum Pumps and Ignition and Excitation Transformers

Each rectifier anode is water-cooled by means of an enclosed thermo syphonic cooling system. The bowl is cooled by means of a circulating system consisting of a fin-tube type radiator, circulating pump and motor-driven blower (Fig. 6). Cooling air is taken from the room and discharged either out-of-doors or within the room. This has eliminated the necessity of installing a heating system. Water is conducted to and from the rectifier bowl through brass pipes, the cooler, pump, and piping being insulated from ground to reduce electrolytic action to a minimum. The systems are arranged to operate in any of three ways, (1) as a closed system, (2) from the city main or (3) in combination. Water enters the jacket of the bowl at the cathode, passes up and through the anode plate, into the jacket surrounding the mercury condensation chamber and out of the top. Temperatures are indicated by a thermometer in the anode plate. Contacts are arranged at 53 deg. cent. for lamp indication and 60 deg. cent. for tripping the d-c. breaker.

Vacuum is maintained in the bowl through the medium of a two-stage vacuum pump. The high vacuum stage is of the mercury vapor type and discharge to the suction of a motor driven rotary pump which operates in oil. Energy for the heating plate of the mercury pump is obtained through a one-phase auxiliary isolating transformer.

Fig. 6—View Showing Blowers and Circulating Pumps

Absolute pressure within the bowl is measured by means of a four-element resistance. Two elements are in vacuum and two in the atmosphere. The variation in absolute pressure causes a variation in temperature thus varying the resistance in the circuit and the vacuum is indicated by means of a millivolt-meter, calibrated in microns. Energy for this circuit is obtained through an isolating transformer in the rear of the switchboard. Average absolute pressures range between three to five microns; the rectifiers will operate with absolute pressures as high as 10 to 20 microns.

Ignition is accomplished by energy from an isolating transformer and reactor. When the circuit is closed the ignition coil is energized through the ignition relay and the rod is drawn down against the action of a spring into the mercury forming the cathode. As contact is made the relay deenergizes the coil and the rod is drawn upward striking the arc. An arc is then established between the excitation anodes and the cathode and the unit is ready for service.

The switchboard consists of 20 panels, 14 of which control the outgoing 600-volt, d-c. feeders, five control

the rectifiers and one the incoming lines, auxiliary power and battery charging equipment. The only special features on the board are the auxiliary change-over switch, the thermal tripping relay on the rectifier d-c. breakers and the absolute pressure indicators which have been mentioned.

At Stratford, the automatic equipment has the usual protective devices such as overload, low-voltage, phase balance, overheating, failure of water, vacuum failure, etc.

Operation of the Bridgeport station commenced on August 15, 1927 and all units were in service on September 15th. The Stratford station commenced operation on December 2, 1927. During the first few months many operating difficulties were encountered as is usual when new installations are first put into service. These troubles were all of a minor nature and are now practically eliminated. The difficulty that has caused the greatest concern is telephone interference. This was much more severe at Stratford than at Bridgeport due no doubt to greater exposure of the telephone circuits. A temporary reactor installed in the negative bus and resonant shunts in the rectifier circuits have practically eliminated this trouble and it is hoped, that with the installation of the permanent equipment, it will disappear entirely.

Since October 1, 1927 records show that there have been 70 instances where service has been interrupted from various causes. None of these outages has been of longer duration than four min., the majority being of but one min. These may be subdivided as follows: High-tension disturbance 5-8 min.; overload 7-9 min.; d-c. disturbances 10-19 min.; back-fire at anodes 26-30 min.; due to construction work 7-13 min.; unknown 15-34 min. Total 70-113 min.

That conditions have greatly improved is evidenced by the record for 27 days of January during which there have been but four "back-fires" and total outage of five min. for the period. After four months of operation experience indicates that there is no question but what the rectifier will prove as reliable, if not more so, than the synchronous converter.

Its operation also is much simpler than the converter; it requires much less attention, and can be put into service on a few seconds' notice. The operator is not required to concern himself as to the equal division of load between the units he may have in service. This division automatically balances itself when a unit is put into or taken out of service. Voltage regulation is good it varying but little over five per cent between no-load and full-load.

No definite information is available on what actual maintenance costs will be as the stations have not been in service a sufficient length of time to give any positive indication thereto. However, it is practically a certainty that it will be much less than for a converter station. This is evidenced by the fact that it has been found possible to make the most extensive repair that can be expected on a rectifier in three working days using three men. To date the only replacements made on all seven rectifiers are; one anode gasket, one excitation anode bushing, and one ignition rod bushing. The reason for these replacements is no doubt due more to handling than to any other cause as no trouble has been experienced from overheating.

The efficiency of the rectifier is unquestionably greater than that of any other type of converting equipment. All tests that have been made have included the power used for the operation of the auxiliaries and for loads from 70 per cent to 100 per cent show an efficiency of from 92 to 93 per cent. Daily operating logs from the station for loads ranging from 48 to 55 per cent capacity factor show an efficiency of from 90.5 to 91.8 per cent.

Considered from all phases, the initial performance of the Bridgeport and Stratford Rectifier Stations has been very gratifying. During the short period that they have been in service, they have demonstrated clearly that they are efficient and reliable and there is no question but that in a few years, as experience indicates, developments will be made in the design of the rectifier that will give it first choice in all installations where the conversion of alternating current to direct current is concerned.

MUNICIPAL AIRPORTS

The Aeronautics Division of the Department of Commerce, has reported that the municipality airports in the United States on August 15, 1928, the 25th anniversary of flight, numbered 367. There are also 331 private and commercial airports, while intermediate landing fields maintained by the Department number 256. The Army has 62 airports and there are 17 naval aviation fields.

The Department of Interior has drafted blank leases for the use in establishing the status of airports established on public lands. The regulations for governing the licensing of these lands may be obtained from the Secretary of the Interior. These regulations were issued in accordance with an Act of Congress approved May 24, 1928, Public 499, entitled "An Act to Authorize the Licensing of Public Lands for Use as Public Aviation Fields."

Assistant Secretary of War, F. Trubee Davison, in a recent address, urged all organizations interested in civic welfare of their communities to cooperate in securing a marking of their towns in such a manner as to be of assistance to aviators in flying over those communities to locate their bearings.

The Aeronautics Branch of the Department of Commerce recently announced that there are 26 companies in the United States operating 32 airways over 13,121 miles, with planes flying 31,240 miles daily. This air mileage is soon to be increased to 15,869 miles when the 2738 miles of airways now scheduled to become active is put into operation. Of this total mileage, 14,502 miles are air mail lines.

Electric Welding

ANNUAL REPORT OF THE COMMITTEE ON ELECTRIC WELDING*

To the Board of Directors:

During the past year, marked progress has been made in the application of electric welding to an increasing number of industrial uses including welding of pipe, pipe lines, structures and cracking stills for gasoline production. A few outstanding applications are mentioned by way of example in the following paragraphs.

One of the largest welding jobs completed during the year was the Mokelumne River Project, a pipe line supplying water to Oakland and other Bay Cities near San Francisco. This line is 90 mi. long. The pipe is 66 in. in diameter and its thickness varies from 3/8 in. to 5/8 in. depending on the water pressure in the particular section of pipe. This job is completed and is, so far as known, the largest single job of welding which has ever been undertaken.

This pipe was so large that it was necessary to join two plates in order to get the required diameter, one joint being made on each side of the pipe. These were welded by the automatic carbon-arc welding process. After each section of the pipe was welded, it was tested by hydraulic pressure at a fiber stress of about 23,000 lb. per sq. in., and while under this pressure, heavy sledges were dropped from a 4-ft. height on each side of the joint, the sledges being one foot apart. This gave a shock test to the joint at the time when it was subjected to the maximum hydraulic pressure.

The contract price on this job of arc welding was twelve million dollars. The best figure offered for the same pipe riveted was fifteen million dollars.

During the year, 45 mi. of 7-in. oil pipe line was electrically arc welded in Louisiana. The pipe was made in the ordinary way and the ends of the pipe were welded. The chief advantage of this method is that the finished pipe line is free from the leakage that sometimes occurs at joints made by threaded couplings in the old way.

This pipe was welded at $1.25 per joint contract price. According to the people who did the welding, the actual cost was 58 cents per joint. The best proposition for welding this pipe by any other method than the metallic arc was $2.75 per joint.

During the year, a number of cracking stills for the production of gasoline from crude oil were welded by the A. O. Smith Corporation. They have been put into service for carrying pressure as high as 1000 lb. to the square inch and a temperature as high as 900 deg. fahr. This is work which can be done only by the welding process. The results cannot be accomplished at all by the older riveting process.

Four papers on electric arc welding were presented at the Winter Convention of the Institute. One of these papers by J. B. Green[1] of the Fusion Welding Corporation dealt with the influence of the covering of the electrode on the characteristics of the arc. During its presentation slow-motion pictures of the arc taken with infra-red light were shown. These disclosed how the metal goes across the arc from the electrode to the work.

The paper by P. Alexander[2] of the Research Department of the General Electric Company at Lynn, Mass., dealt with the influence of the surrounding atmosphere on the arc.

The paper by A. M. Candy[3] of the Westinghouse Electric & Manufacturing Company described a five-story building recently erected by welding, and a paper by A. P. Wood[4] of the General Electric Company described what is being done at Schenectady in the way of welding electric machines of all descriptions.

Since that time, a bridge has been erected by welding by the Westinghouse Company at their plant at Chicopee Falls. This bridge has 80 tons of structural steel in its construction and would have required 120 tons if it had been erected by the riveting method in the regular way.

Early in 1928 three prizes offered by the Lincoln Electric Company for the best papers on electric arc welding through the American Society of Mechanical Engineers were awarded by a committee of seven judges representing the Engineering Societies and the Bureau of Standards.

The first prize of $10,000 was awarded to J. W. Owens of the Newport News Shipbuilding & Dry Dock Company, for a paper on "Electric Arc Welding in Ship Construction."

The second prize of $5000 was awarded to Professor H. Dustin of Brussels, Belgium, for a paper covering the method of calculating the strength of welding, giving data not heretofore available.

The third prize of $2500 was awarded to H. E. Rossell of the Philadelphia Navy Yard on the use of electric arc welding in the construction of bulkheads.

The American Welding Society has had committees on structural-steel welding and on pressure-vessel welding at work during the year and substantial progress has been made in the work of the committees, although no final report has been issued.

J. C. LINCOLN, *Chairman.*

*COMMITTEE ON ELECTRIC WELDING:

J. C. Lincoln, Chairman.

C. A. Adams,	Alex. Churchward,	Ernest Lunn,
P. P. Alexander,	O. H. Eschholz,	J. W. Owens,
C. W. Bates,	F. M. Farmer,	William Spraragen,
Ernest Bauer,	H. M. Hobart,	H. W. Tobey,
A. M. Candy,	C. J. Holslag,	Ernest Wanamaker.
	C. L. Ipsen,	

Presented at the Summer Convention of the A. I. E. E., Denver, Colo., June 25-29, 1928.

1. A. I. E. E. Quarterly TRANS., No. 2, Vol. 47, 1928, p. 820.
2. Ibid., p. 706.
3. Ibid., p. 711.
4. Ibid., p. 717.

The Communication System of the Conowingo Development

BY W. B. BEALS[1] Member, A. I. E. E. and E. B. TUTTLE[2] Member, A. I. E. E.

Synopsis.—This paper describes the communication system which has been installed to serve the power plant at Conowingo, Maryland, and its associated transmission line.

The important features to be considered in designing a telephone system for a power plant are pointed out. The types of telephone switchboard and telephone instruments chosen in this case to meet the special requirements of the generating station, together with the layout and cabling arrangement, are outlined

The paper also discusses the possible ways of providing for the needs of the load dispatcher and the plan adopted at Conowingo; the facilities provided the patrolmen for calling from points along the transmission line; the connection from the private branch exchange to the general telephone system; and the special electrical protection installed on the long lines leaving the power house.

1. Introduction

THE proper functioning of a power plant and distribution system depends to a large extent upon the ability of the operating force to communicate easily and promptly with one another. Therefore, the details of design of a power system may be influenced by a consideration of the various possibilities of telephone communication.

The design of a telephone system to meet the needs of a generating station such as that at Conowingo and the transmission network associated with such a system, requires the closest cooperation between the power and telephone engineers and a thorough understanding of each other's problems.

Among the important features to be considered in this cooperative work are:

a. Continuity of service.

b. Means for quick communication with any part of the generating station.

c. Location of telephones so that they can be used without taking power-house employees away from their working stations.

d. Means for communication between the generating station, system operator, and points along the transmission line.

e. Protection for the circuits connecting with the general telephone system.

All of the features in the above list were given very careful consideration in designing the telephone system for the Conowingo project.

The essential elements of such a telephone layout consist of a private branch exchange switchboard which provides convenient means for connecting a telephone in one part of the plant with a telephone in another location or with telephone central offices; telephone distribution cables running from the switchboard to the locations where the telephones are installed; circuits running from the branch switchboard to the central office of the telephone company; and finally, the telephones themselves so located as best to meet the needs of the people who are to use the system.

2. Private Branch Exchange and Associated Power Plant

(*a*) *Conditions To Be Met and Type Adopted.* The Conowingo power house is located within the area served by the Darlington, Maryland, Central Office. In the Darlington central office area, the service is of the magneto type (*i. e.*, hand generators are used for signaling and dry cells are installed at each telephone set to supply talking battery). In such an area it is usual to furnish private branch exchange equipment of the same type. At the Conowingo power house, however, in view of the size of the installation and the fact that it lends itself better to some of the rather special arrangements needed at certain places in the power house, it was decided to use the common battery type of telephone system where the telephone user signals the operator by simply lifting the receiver off the hook.

The adoption of the common battery type of private branch exchange in the Darlington central office area necessitated certain modifications in the usual type of switchboard in order to furnish lamp signaling and supervision and at the same time to operate on connections to the magneto central office switchboard at Darlington.

The operating battery consists of eleven cells of the enclosed radio type and is kept in a fully charged condition by a small, full-wave rectifier, operated from the local lighting circuit and adjusted to trickle charge the battery continuously. The battery has sufficient capacity to operate the telephone system for some time in case of trouble with the rectifier or the local lighting circuits.

Regular and emergency ringing interrupters are installed for supplying energy to ring the various tele-

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Presented at the Regional Meeting of the A. I. E. E., District No. 2, Baltimore, Md., April 17-19, 1928.

phone stations and the central office of the telephone company. A hand generator is also installed in the switchboard for emergency use.

Alarm signal equipment, consisting of a bell and lamps, is provided to indicate the operation of a charge or discharge fuse on the battery, the failure of the a-c. service or the burning out of a rectifier tube. Spare fuses and rectifier tubes have been conveniently located for replacements in case of failure.

(*b*) *Location and Layout of Private Branch Exchange Equipment.* The private branch exchange switchboard is installed in the main control room and adjacent to the power switchboard operator's desk, so that it can be operated by the power switchboard operator when desired. It is equipped for handling 70 common battery lines, 10 local battery lines and 5 central office trunk or long tie lines (such as lines to Philadelphia). Provision has been made for further trunk and tie line growth.

In the usual private branch exchange all relay and signaling equipment is contained in the telephone switchboard framework. The modifications at Conowingo required a number of additional relays and repeating coils which the switchboard would not accommodate. These relays and coils have been mounted on a small rack similar in design to those used in small telephone central offices. Since the ultimate layout of the main control room would not permit the installation of this rack adjacent to the telephone switchboard, it has been placed in another room as close as possible to the board.

From the telephone switchboard lead-covered cables extend to a cross-connecting main frame which permits the association of any cable pair in the distributing cables to the telephone stations, or, in the cable leading out of the power house, with the proper switchboard terminal. The distributing frame is of the type used in small telephone central offices and carries the standard telephone protectors. It has been located in the same room assigned to the telephone power plant. This room is close to the center of distribution of the telephones which will ultimately be needed and will, therefore, permit of the most economical distribution cable layout.

3. Telephone Station Equipment and Distribution Cable

(*a*) *Requirements and Types Adopted.* As mentioned previously, the main requirements of the apparatus to be installed in the power station are simplicity of operation, durability and compactness. The first of these has been met by the adoption of common battery signaling equipment. To meet the second and third conditions the telephones have been placed in recessed cabinets in the walls. Each cabinet is designed to hold a standard desk stand and bell box and is provided with a door which lets down to serve as a shelf when the telephone is in use. When the telephone is not in use, the door is kept closed and the apparatus is out of the way in a protected location. This method of installation is general in the power stations and substations of the Philadelphia Electric Company.

At the gage board at each of the machines, under certain conditions it will be necessary for attendants to take orders over the telephone, read the meters, and adjust apparatus at the same time. In order to meet this condition and still avoid the possibility of having telephone apparatus in a position where it might be in the way, a jack has been provided at each of the gage boards, and operators' telephone sets with chest transmitters and head receivers with extension cords have been provided in convenient locations for use with the jack ended circuits. The jacks are enclosed in dust-proof boxes and are connected to two circuits terminating on the switchboard, one circuit terminating at the panels for service generators Nos. 1 and 2 and main generators Nos. 1 to 4 and the other circuit at the panels for present and future main generating units Nos. 5 to 11. With this arrangement the station attendants can talk over the telephone and yet have both hands free for whatever they are required to do.

Telephone stations have been provided along the dam for use in making reports from points in the vicinity of the gates. Since these stations are in locations which will always be subject to a certain amount of moisture, mine type sets have been installed in recessed cabinets located at convenient points along the parapet wall. These cabinets are provided with metal frames and covers and are kept locked in order to prevent use of the telephones by unauthorized persons. Mine type sets have also been provided on the observation platform near the spillway and in the inspection tunnel in the vicinity of the butterfly valves.

Five mine type sets have been installed on the steel framework of the substation located on the roof of the power house, some points of which are 85 ft. above the level of the roof. They provide a means of communication with men working on the 220-kv. disconnecting switches. Four additional mine type sets have also been installed at various locations on the roof of the power house. In addition to these telephones, four jack-ended circuits have been mounted inside of the mine type sets on the roof. Durable, moisture proof extension cords terminated at one end in a plug for connection to the jack-ended circuits and at the other end in a small jack box have been provided for the use of men working on the inside of the 220-kv. circuit breaker tanks. The jack boxes are arranged to be attached to the workmen's belt in order to leave both his hands free. A regular telephone operator's set with a short cord and plug is provided so that the workman may insert the plug in the jack box on his belt. This gives an easy means of communication between the men working in the circuit breaker tanks and men outside.

In the office bay, standard desk set equipment has been provided for office employees.

(*b*) *Cabling Layout.* In view of the conditions to be met in rendering telephone service in power stations, the telephone circuits are for the most part in lead-covered cable except that the runs from cable terminals to the individual stations are made with single pair twisted wire. These cables vary from 11 to 101 pairs each and are run through metal conduit, installed for this purpose when the concrete of the structure was poured. The telephone conduits are separated by several inches from the conduits carrying lighting and other distribution circuits in the power house, and are bonded to the power system ground so that in case of any faults on the power circuits it is expected that resulting voltages and stray currents will not introduce a hazard on the telephone circuits. The installation of telephone cables of the size employed in the power house necessitated placing "pull boxes" at frequent intervals along the conduit runs.

The distribution cables to the stations are terminated in five main terminal boxes where the individual cable pairs can be connected to the wires running to the various stations. This permits of considerable flexibility in cable pair assignments, and makes it possible readily to interchange cable pairs in case one becomes defective or to replace a short section of cable without interfering with the rest of the circuits in the telephone plant.

4. Outside Lines

(*a*) *Trunk Lines and Outside Stations.* The private branch exchange is connected with the telephone company's central office at Darlington, Maryland, by means of two circuits which are carried out of the power house in lead-covered cable and thence by open line wires to the central office. The same cable carries a few lines to stations located in the employees' houses not far from the dam.

(*b*) *Load Dispatching Circuits.* In any power transmission system the operations requiring coordinated action at power sources and substations make it imperative that communication be established quickly and maintained without interruption between the load dispatcher and the operating units.

As the system is extended to include more than one source of supply the necessity for this close supervision on the part of the load dispatcher is very greatly increased by the need for proper distribution of loads. This supervision may be secured by automatic operation or through communication with an operating force.

At the A. I. E. E. Midwinter Convention in Philadelphia in February 1924, two papers were presented describing apparatus for distant operating by mechanical means. The use of this equipment places in the hands of the load dispatcher the means of regulating generators and loads by his own personal actions and in certain cases generating plants and substations can be very satisfactorily operated in this manner. Associated with the mechanical operation of these systems there must be visual indication of their conditions by such means as distant metering, gaging, etc.

With power units and substations of such size as are involved in the Conowingo project, personal attendance becomes imperative for a number of reasons, and therefore system operation from a distant point through mechanical agencies was deemed not suitable for this installation.

Several methods which present themselves, *viz.*, telephone, telegraph, and printing typewriter were considered in setting up the load dispatching system for the Conowingo power project. The extensive existing load dispatching system of the Philadelphia Electric Company system had a great influence in deciding what extensions should be made to care for the interconnection with the Conowingo project. This existing system consists of private lines leased from the telephone company and connecting the various substations and generating centers with the general office building of the company. At this location the lines terminate in a magneto switchboard in the office of the load dispatcher who can thus secure instant direct contact with the various units of the system.

This system is reserved for the exclusive use of the load dispatching forces and no connection is provided to the telephone company's exchange system except through an emergency circuit on the board in the load dispatcher's office.

Direct telephone company facilities were, therefore, found most suitable in the extension to Conowingo of the load dispatching system. In planning this extension, two prime factors were considered to be highly important, continuity and reliability of service. To provide for the former, it was decided to supply both regular and emergency circuits routed through separate cables or over separate pole lines so that in the event of ordinary maintenance troubles which might affect one circuit, the second would be available. The reservation of both of these circuits for load dispatching exclusively is not warranted, and provision is made for one to be used between the private branch exchanges provided for general telephone business, but to be available to the load dispatcher by means of loop jacks in his private line switchboard. This latter arrangement permits the load dispatcher to take over the use of the second circuit and clear any conversation that it may be carrying.

The second requirement, reliability, presented the more difficult engineering problem, as it will in any similar situation. The telephone company had existing plant for the entire distance from the Conowingo site to the headquarters of the Electric Company at 10th and Chestnut Streets, Philadelphia, consisting of underground cable plant between Philadelphia and Havre de Grace at the mouth of the Susquehanna River connected to an open wire pole line from Havre de Grace to the power site. Underground plant is, of course, most reliable, but the open wire line may be interrupted during heavy sleet and wind storms.

The power company has a continuous private right-of-way from Conowingo to Plymouth Meeting. This right-of-way is free from trees and other obstructions, but proximity to the high-voltage transmission line rendered it unsuitable for communication circuits.

Various means of securing telephone service were studied, including carrier current systems on the power transmission lines and short wave radio. At the time this paper was prepared, consideration was being given to the desirability of building a new pole line on a private right-of-way, cleared of trees and shrubs, from Havre de Grace to the power site. The poles and wires would be so spaced and of such strength as to be capable of withstanding ice and sleet loads such as have been encountered in the past.

While load dispatching is of prime importance in setting up communication service, there are other important uses which cannot be neglected. Many routine matters of operation and maintenance can best be handled by telephone and facilities to do this must be provided. Many power companies do not feel that it is necessary to reserve the dispatching circuits exclusively for that service and use the same circuits for the transaction of general business. However, with the demand on the power companies for continuous service by trunk line railroads and city water supply systems, etc., the necessity of immediate communication for load dispatching purposes becomes more exacting. For this reason the Philadelphia Electric Company decided to provide a second circuit to care for general business and make this second circuit available in emergencies for load dispatching purposes as outlined above.

(*c*) *Patrol Stations.* Another important communication service is that provided for the use of patrolmen. Regular telephone service by means of telephone stations connected to the nearest central office of the telephone company offered opportunity for patrol service over the regular toll lines of the telephone system. With the increased speed of service now provided over these lines dependable and rapid connections can be obtained. This method has the advantage over a single patrol circuit, in that in case of failure of one toll line, alternate routes are available. If the number of patrol stations is small and the calls infrequent, this service is also less expensive.

This method was adopted for the Conowingo system and four patrol stations have been established between Conowingo and Plymouth Meeting, each with the telephone located in a building owned by the Power Company and located on its right-of-way.

(*d*) *Special Protection.* Preliminary computations indicated that at time of fault on the 220-kv. transmission line, ground currents of considerable magnitude would flow through the station ground connection, and even if the impedance of the ground connection were as low as a fraction of an ohm, there would be a considerable rise in ground potential in the neighborhood of the dam.

A rise in ground potential at the dam with reference to the ground at the other terminals of the circuits connected to the private branch exchange might operate the telephone protectors and result in interruptions to telephone service at times when it was most needed. These potentials would also be effective between the telephone circuits and ground in any location outside the area affected by the power system ground.

Since all metallic structures in the power house are thoroughly bonded to the same ground; no potential will exist between telephone equipment and other metallic structures in the power house unless the telephone be connected metallically to a circuit extending outside the area within which a considerable difference in ground potential is caused by the fault.

Due to the extensive grounding system, consisting of ground plates, water pipes, the steel reinforcement of the dam itself, and numerous other metallic structures in the power plant, the most practical method of avoiding interruptions to service coincident with failures on the power line seemed to be, in this case, to isolate the portions of the long circuits within the area in which potentials considerably different from outside points might be expected.

Tests were made jointly by the power and telephone interests to determine the impedance of the power system ground connection and the extent of the area which might be at potentials substantially different from those at distant points. These tests were made by feeding current through a ground established at some distance from the power station back to the power station ground and measuring the difference in potential between the power station ground and the telephone central office grounds at Darlington and Belair, Maryland, as well as at intermediate points. These tests indicated that the impedance of the power system ground was at that time between 4/10 and 5/10 of an ohm and that the potentials of points along the west bank of the river and in the Stone and Webster company's construction camp close to the dam varied only about three per cent from the potentials impressed on the power station ground. It was also found that the potential of the water system in the power company's village about 3000 ft. from the dam was only about 6 per cent lower than the potential at the dam and that the potential at points in the village about 100 ft. away from the nearest water pipes was only about 15 per cent different from the potential at the power plant. Further measurements indicated that the earth potential gradient along the telephone line toward Darlington central office was quite gradual and a slight rise in potential was noted even at the Darlington central office, more than two miles from the dam.

A point about a mile away from the dam at the edge of the power company's property where the circuits to the private branch exchange leave the telephone company's line was selected as the most practicable location for insulating transformers to be used in isolating the

telephone plant in the area within which substantial rise in ground potential might be expected. The measurements indicated that about 65 per cent of the total drop in potential occurred between this point and the power station ground.

Western Electric Company's No. 50-A repeating coils, insulated between windings for 25,000 volts, have been installed at this point, with lightning arresters on both sides of these coils. The breakdown voltage of these arresters is such that they will not be operated by any rises which it is expected may occur in the potential of the power station ground.

Conclusion

As indicated above, the proper functioning of a power plant and distribution system depends to a considerable extent upon the provision of an adequate communication system by means of which the operating forces can promptly and easily communicate with each other.

In many cases the provision of such a communication system requires the solution of numerous special problems and these are illustrated in this paper by the special problems involved in the design of the communication system of the Conowingo project.

Cooperative consideration by power and telephone engineers of all the available means of communication at an early stage in planning the project, and the adoption of the means most suitable in the specific case should result in the provision of a communication plant of the greatest effectiveness in the operation of the power system.

Electric Transportation

ANNUAL REPORT OF COMMITTEE ON TRANSPORTATION*

To the Board of Directors:

The application of electricity to transportation proceeded during 1927 at a healthy rate, and new developments in apparatus and equipment continued, several interesting applications being introduced during the year.

Steam Railroad Electrification

Although no new electrification projects of major importance were completed during the year of 1927, two extensions were opened which had as their particular aim the further simplification of electric operation already existing, *viz.*, the Bay Ridge extension of the Long Island Railroad permits electrically-operated freight trains from the New York, New Haven & Hartford Railroad to pass over the Hell Gate Bridge Route to the tidewater freight terminal at Bay Ridge, Long Island; the Chicago, Milwaukee, St. Paul & Pacific Railroad has electrified its passenger terminal in Seattle, Washington, together with its line from Black River Junction over which trains had previously been handled by steam power.

Of the incompleted projects: the Pennsylvania Railroad will place in service shortly its suburban electrification from Broad Street Station, Philadelphia, to Wilmington, Del. and West Chester, Pa. The Great Northern Railway is proceeding with the extension of electric operation from Cascade Tunnel to Wenatchee, Washington. The New York Central Railroad is electrifying its west side freight yards in New York City. The New York, Westchester & Boston Railway is continuing its line to Port Chester, N. Y. The Detroit, Toledo & Ironton Railroad is working on the extension of its existing electrification from Flat Rock on to Petersburg, Mich.

The principal new project getting under way at the present time is the electrification of the suburban lines of the Reading Company around Philadelphia, Pa. It has been announced also that the Boston, Revere Beach & Lynn Railroad is planning to electrify its line.

Of electrifications placed in service during the year of 1926, one of the most interesting, the Chicago Terminal electrification of the Illinois Central Railroad, reports a marked increase in traffic and revenue for the first year of operation.[1]

Long Island Railroad. The Bay Ridge extension of the Long Island Railroad has been electrified with the 11,000 volt overhead catenary, single-phase, 25-cycle system for freight operation. This line joins the Bay Ridge freight terminal of the Long Island Railroad with the New York Connecting Railroad's Hell Gate Bridge Route to the New York, New Haven and Hartford Railroad at Port Morris, N. Y. The route is 20 miles in length.

Power is transmitted over a 22,000-volt, three-wire system with 11,000 volts between trolley and ground, and is received from the New Haven Railroad distribution system; in emergency it can be obtained from one 5000-kw. variable ratio frequency changer at the Long Island's East New York substation. This frequency changer is normally used as a synchronous condenser for power factor correction. No. 4/0 copper feeder wires are connected to the trolleys through auto-

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*COMMITTEE ON TRANSPORTATION:

J. V. B. Duer, Chairman.

Reinier Beeuwkes,	John Murphy,	N. W. Storer,
E. R. Hill,	W. S. Murray,	H. M. Vandersluis,
W. K. Howe,	W. B. Potter,	Richard H. Wheeler,
D. C. Jackson,		Sidney Withington.

Presented at the Summer Convention of the A. I. E. E., Denver, Colo., June 25-29, 1928.

1. *First Year of Electric Operation in Chicago*, by W. M. Vandersluis, A. I. E. E. Quarterly Trans., Vol. 47, 1928, No. 1, p. 217.

transformers at six balancer substations, four of which are on the Long Island and two on the New York Connecting Railroad.

The catenary system is non-ferrous with a single 4/0 bronze contact wire, copper auxiliary wire and high-strength bronze messenger wire. Inclined catenary is used in general on curves. The supports consist largely of rolled structural "H" beams. Rails are bonded with two No. 1 copper, 37-strand flame-welded bonds per joint.

The seven double-unit, gear-drive locomotives built for switching service have a wheel arrangement of 0–6–0 + 0–6–0, and weigh 158 tons each. The six motors on each complete locomotive are rated at 235 volts and operate with forced ventilation. The maximum starting tractive effort is 100,000 lb. and can be obtained up to 7½ mi. per hour. The maximum operating speed is 25 mi. per hour. Through traffic is handled by New Haven locomotives.

In addition to the Bay Ridge a-c. electrification, the Long Island Railroad is adding to its d-c. operation to the extent of 75 mi. of freight tracks and sidings, which will allow electric operation of all freight service within the electrified portion of the railroad. The work is 50 per cent completed and is to be completed by October 1st, 1928. A special "T" section third-rail of high conductivity is being used for all sidings and yard tracks.

Chicago, Milwaukee, St. Paul & Pacific Railroad. The western terminal of the Chicago, Milwaukee, St. Paul & Pacific are Seattle and Tacoma, Washington. Electric service ran into Tacoma, and service to Seattle had been handled by steam from Black River Junction. During the year of 1927, the line, 10 mi. of double track from the junction into Seattle, was electrified. Power is furnished from the earlier electrification through the overhead distribution system, and no new substations were constructed. This electrification is 3000-volt, d-c., with an overhead catenary system having a double contact wire.

Pennsylvania Railroad. The Pennsylvania Railroad is completing the electrification of its suburban service from Philadelphia, Pa., to Wilmington, Del., on its main line to Washington, and to West Chester, Pa., on the Wawa Branch. This project was outlined in last year's report. Overhead catenary is used, energized with 11,000-volt, 25-cycle, single-phase current.

Great Northern Railway. The project of the Great Northern Railway to electrify its line between Wenatchee and Skykomish, Wash., is proceeding rapidly. Grade and curvature realinements are being made, and the new Cascade Tunnel from Berne to Scenic, (7.79 mi. long) is more than 65 per cent completed. Electric operation, which now extends from Skykomish through the old Cascade Tunnel, is to be extended through the new tunnel and on to Wenatchee before the end of 1928. The project will operate on 11,000-volt, single-phase, 25-cycle power, using motor generator locomotives with d-c. traction motors.

Orders have been placed for locomotives similar to those which are now in operation; that is, two additional type 2–6 + 6–2 and two additional type 2–8–2 + 2–8–2 locomotives, having continuous ratings of 3000 hp. and 3660 hp. respectively.

New York Central Railroad. The New York Central Railroad is proceeding with the electrification of its west side yards in New York City. The overhead trolley system at 600 volts d-c. is to be used as far down town as 60th Street. Below this the motive power will be self-contained power units.

New York, Westchester & Boston Railway. The New York, Westchester & Boston Railway is completing the extension of its Port Chester, N. Y., line as far as Rye, N. Y. Multiple unit suburban service is operated on 11,000-volt, 25-cycle, single-phase power.

Detroit, Toledo & Ironton Railway. The Detroit, Toledo & Ironton Railway is proceeding with the electrification of 26 mi. of line from Flat Rock to Petersburg, Mich. This will be an extension of the existing 11,000-volt, 25-cycle, single-phase electrified line described in last year's report, which runs from Fordson to Flat Rock, Mich.

Reading Company. The Reading Company is planning extensive improvements in its Philadelphia facilities, and expects to electrify 85 mi. of track with a 11,000-volt, 25-cycle, single-phase system.

Power will be furnished to this electrification over 22,000-volt feeders by a three-wire system with 11,000 volts between the overhead catenary and ground. The eventual program calls for transmission between substations at 66,000 volts.

The initial project comprises multiple unit service from the Reading Terminal in Philadelphia to Chestnut Hill, to Lansdale on the Bethlehem Branch and to Hatboro.

Boston, Revere Beach & Lynn Railroad. The Boston, Revere Beach & Lynn Railroad, a narrow gage line running out of Boston, Mass., plans to electrify a route of 15 mi. It is proposed to use a 600-volt overhead catenary system for multiple unit operation.

City and Suburban Railways

On electric street railways increased acceleration is being obtained by the use of light weight cars and more powerful motors with the latest design of control, thus tending to relieve congestion on city streets.

Trial installations of the new type of drive mentioned in last year's report have been put in service in a number of instances. This is the automotive type propeller-shaft drive by which unsprung weight is greatly reduced, with a corresponding reduction in noise and maintenance. Improved installations have been made in reduction gear drive with entirely spring-suspended motors having a flexible driving joint.

Marine Propulsion

The largest turbine-electric passenger ship, *California*, was launched October 1st, 1927. The displacement is 30,250 tons. Power is supplied to the propellers by two synchronous induction type motors each with a maximum continuous rating of 8500 ship hp. at 120 rev. per min.

The installation of Diesel-electric drive has been extended during the year to include three new lightships for the Department of Commerce as well as coast guard cutters, large double-ended ferry boats, a packet boat, and cargo boats.

Bus Transportation

Gas-electric drive for motor buses and motor coaches is increasingly popular. Experiments have been made on electric transmission for taxicabs.

Recent Developments

Diesel Electric Locomotives. The past year brought forth a novel arrangement of the Diesel engine prime mover with electric drive:

In electrification of its west side yards in New York City the New York Central Railroad has decided to use an overhead contact wire within the city limits only as far down town as 60th Street. Below this point it is desirable to employ a self-propelled unit. The locomotive chosen for this service, therefore, operates on third rail or trolley at 600 volts d-c., or can be propelled by power from a self-contained 300-hp. Diesel engine-driven generator, augmented for peak requirements by a storage battery. When load requirement is for less than 300 hp. the current from this battery is replaced by the generator.

Gasoline-Electric Rail Cars. During the year of 1927, approximately 150 gasoline-electric motor rail cars were ordered by the railroads of the United States. One 300 hp. oil-electric car was placed in service.

Trolley-Storage Battery Locomotive. Two electric locomotives furnished with power from a storage battery and also from an overhead trolley wire are in service for yard switching service on the Chicago, North Shore & Milwaukee Railroad. When the locomotive is receiving current from the trolley the battery is charged by a motor-generator set.

High-Speed A-c. Circuit Breakers. Although oil circuit breakers with rapid operating characteristics have been available for several years in a-c. switching, one of the most interesting developments of the past year has been the construction of an air circuit breaker for operating on 11,000-volt a-c. circuits and having speed characteristics similar to direct current installations. This type, as well as oil circuit breakers operating on the same principle, is to be used by the Pennsylvania Railroad on its extension of electrified suburban service around Philadelphia.

Overhead Catenary. The construction of overhead catenary on the Great Northern Railway electrification from Skykomish to Wenatchee, Wash., is an application of the formula proposed by O. M. Jorstad[2] for inclined catenary.

Supervisory Control. All four transformer substations on the Philadelphia to West Chester electrification of the Pennsylvania Railroad are to be controlled from the Wawa signal tower by supervisory control. The synchronous visual type is being installed.

Another interesting installation of supervisory control is the West Hempstead substation of the Long Island Railroad, now under construction, at which three 1000-kw. mercury arc rectifiers are controlled from Mineola substation two miles away. The rectifiers can be started by the supervisory system in approximately 20 sec.

Train Communication. Radio communication between locomotive and caboose and between train and station has been the subject of considerable experiment. An installation of this type is in service on the New York Central Railroad.

Mercury Arc Rectifiers. The use of the mercury arc rectifiers in electric railway substations is still limited to a few installations. A summary of the operating experience of one railroad with this equipment is contained in a paper entitled *Operation and Performance of Mercury Arc Rectifiers on the Chicago, North Shore & Milwaukee Railroad Company.* This paper was presented by Caesar Antoniono at the Regional Meeting[3] in Chicago, Ill., November 28-30, 1927.

Technical Papers

The committee has obtained for presentation at the 1928 Summer Convention a group of interesting papers. They are as follows:

High-Speed Circuit Breakers, by J. W. McNairy, General Electric Company.

The High-Speed Circuit Breaker in Service on the Illinois Central Railroad, by W. P. Monroe and R. M. Allen, Illinois Central Railroad.

Arrangement of Feeders and Equipment for Electrified Railways, by R. B. Morton, Gibbs & Hill, New York, N. Y.

Operating Experience with High-Speed Oil Circuit Breakers, by B. F. Bardo, New York, New Haven & Hartford Railroad.

High-Speed Circuit Breakers for Railway Electrification Work, by H. M. Wilcox, Westinghouse Elec. & Mfg. Co.

Protection of Electric Locomotives and Cars to Operate with High-Speed Circuit Breakers, by E. H. Brown, Pennsylvania Railroad Co.

2. *Standardized Catenary Design*, by O. M. Jorstad, A. I. E. E. Trans., Vol. 46, 1927, p. 1125.

3. A. I. E. E. Quarterly Trans., Vol. 47, 1928, No. 1, p. 228.

Abridgment of

Application of Large Frequency Converters to Power Systems

BY E. J. BURNHAM[1]
Associate, A. I. E. E.

Application of Large Frequency Converters to Power Systems

In selecting a frequency converter, there are many things which should receive special study and consideration in order that the equipment obtained will meet the necessary requirements in the best possible way.

Types of Frequency Converters

The following types of frequency converters will be considered:

1. Synchronous-synchronous type, consisting of a synchronous motor direct-connected to a synchronous generator.
2. Induction-synchronous type, consisting of an ordinary induction motor direct-connected to a synchronous generator.
3. Adjustable-ratio induction-synchronous type, consisting of a wound rotor induction motor direct-connected to a synchronous generator, the induction motor having suitable control equipment to give a variable frequency ratio between the two systems to be connected together.
4. Fixed-ratio induction-synchronous type, consisting of an induction frequency converter direct-connected to a synchronous generator. The rotor of the induction motor is connected electrically to the stator of the synchronous unit, thereby allowing electrical, as well as mechanical, transfer of power through the set.

Synchronous-Synchronous Type

In the past, the majority of frequency-converter sets used have been of the synchronous-synchronous type because such sets are adaptable to simplicity of design and operation and may have low costs, high efficiency, and ability to correct power factor.

The power factor of either machine of the set may be conveniently adjusted by field control.

The load transferred through this type of set must be controlled by governor adjustments on the prime movers of either or both interconnected systems. Usually, this introduces no great hardship in operation.

Fluctuation in frequency on either or both systems causes load variation on the set, and if the fluctuations in frequencies are sufficiently severe, the set will pull out of step.

Fig. 1 shows a 20,000-kw. 300-rev. per min. synchronous-synchronous frequency converter recently placed in operation. The 60-cycle machine is rated three-phase 11,000 volts unity power factor and the 25-cycle machine is rated single-phase 11,000 volts unity power factor. The tested over-all efficiency of the set is 96.26 per cent.

Induction-Synchronous Type

Sets of the induction-synchronous type consist of an induction motor driving a synchronous generator. The frequency ratio varies slightly with load on the set, due to the slip of the induction motor. The straight induction motor, of course, in itself lacks the ability to correct power factor.

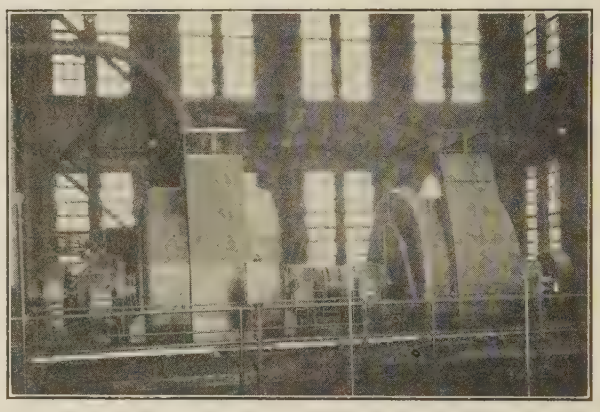


Fig. 1—20,000-Kw., 300 Rev. per Min. Synchronous-Synchronous Frequency Converter

Adjustable-Ratio Induction-Synchronous Type

By means of frequency-converter sets of this type, flexible frequency ties are formed between the systems connected with each other. The two main units consist of a synchronous machine direct-connected to a wound-rotor type induction machine.

The outstanding features of this type of set are as follows:

1. The ratio of the two system frequencies may vary.
2. Direction and amount of load transferred through the set may be controlled at the set itself.
3. The speed of the set may be controlled for synchronizing purposes.
4. The capacity of the set is determined only by the amount of power to be transferred through the set, as

1. Central Station Engg. Dept., General Electric Co., Schenectady, N. Y.

Presented at the Regional Meeting of Northeastern District, No. 1, of the A. I. E. E., New Haven, Conn., May 9-12, 1928. Complete copies upon request.

it is not necessary to furnish synchronizing power to hold the two systems together.

5. Leading current for power-factor correction may be furnished by the set to either system.

6. System disturbances will not pull the set out of step as easily as a set of the synchronous-synchronous type.

Operation is based upon the fundamental principle

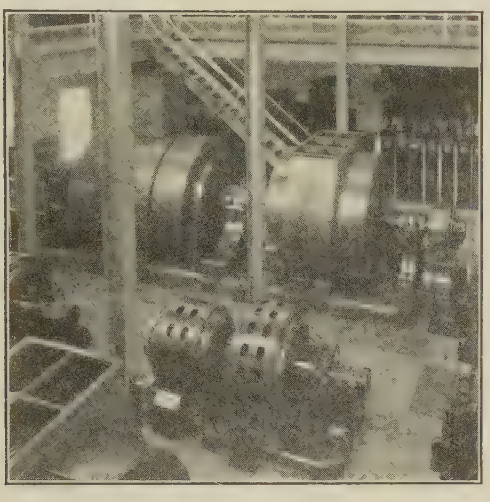


Fig. 2—6000-Kw. Adjustable-Ratio Induction-Synchronous Frequency Converter

Regulating set is shown in foreground—Installation is in Rochester substation

that the speed of an induction motor may be controlled by controlling its secondary voltage.[2]

A regulating machine inserts a voltage of slip fre-

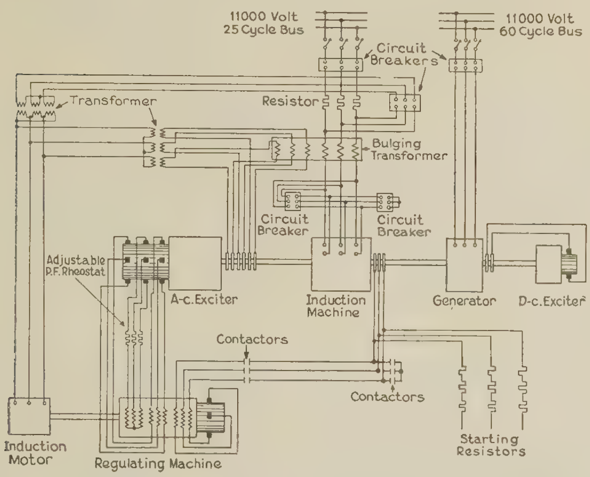


Fig. 3—Diagram of Connections for a 6000-Kw. Adjustable-Ratio Induction-Synchronous Frequency Converter

quency in the rotor circuit of the induction unit. When this regulating machine operates as a motor, power is taken from the induction motor rotor, just as would be the case if a resistor were used, but with less loss. When the regulating machine operates as a generator, it corresponds to a negative resistance placed in the induction motor rotor circuit, furnishing power to the induction motor rotor, and giving speed control above synchronism.

Seven adjustable ratio frequency converters of the Scherbius-controlled type are now in operation. Five of these sets are rated 6000 kw., and two are rated 5000 kw.

A wiring diagram of the Rochester 6000-kw. Scher-

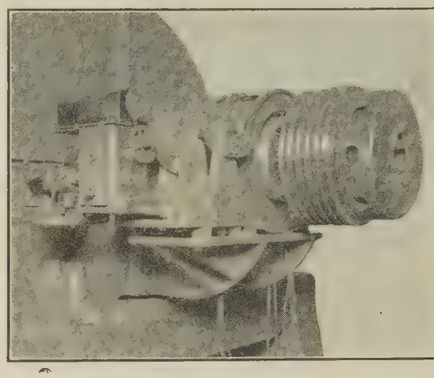


Fig. 4—A-c. Exciter for a 6000-Kw. Adjustable-Ratio Frequency Converter

bius-controlled, adjustable-ratio frequency converter set, is shown in Fig. 3.

Regulating Machine

The requirement of the regulating machine is to supply a voltage to the collector rings of the main

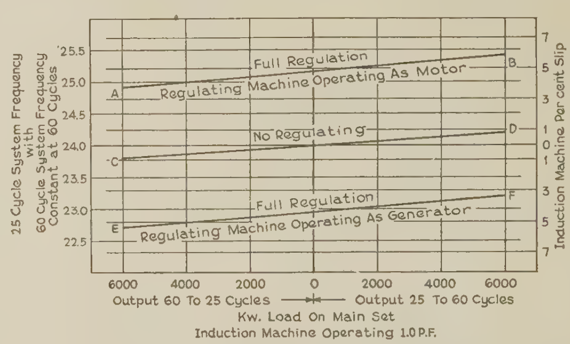


Fig. 5—Operating Characteristics of a 6000-Kw. Adjustable-Ratio Frequency Converter

induction unit, this voltage being at slip frequency and having a magnitude and phase angle controllable by the operator.

The regulating machine has the characteristic that whatever frequency is used in its excitation, voltage of that same frequency will appear at the armature terminals. This required excitation is obtained from the a-c. exciter mounted on the shaft of the main set, as shown in Fig. 3.

A-c. Exciter

Fig. 4 shows a close-up view of the a-c. exciter.

2. *Theory of Speed and Power Factor Control of Large Induction Motors by Neutralized Polyphase A-c. Commutator Machines*, by J. I. Hull, A. I. E. E. Trans., 1920, Vol. 39, p. 1135.

"Three-phase Speed Regulating Sets with Separate Excitation," *E. T. Z.*, 47, p. 989, Aug. 26, 1926.

The rotor of this unit has both collector rings and a commutator, and is similar in construction to the rotor of a rotary converter. The a-c. exciter is really a frequency-changing exciter, as it receives power at line frequency and converts, it into slip frequency.

Control of Regulating Machine Voltage

The load field of the regulating machine is connected to two sets of brushes on the a-c. exciter commutator, as shown in Fig. 3. By shifting these two sets of brushes in opposite directions, the brushes are permitted to span a greater or less number of commutator bars, thereby furnishing the means of obtaining variable voltage for exciting the load field of the regulating machine. This brush-shifting mechanism is motor-operated, so the brushes may be shifted either automatically, or by the operator.

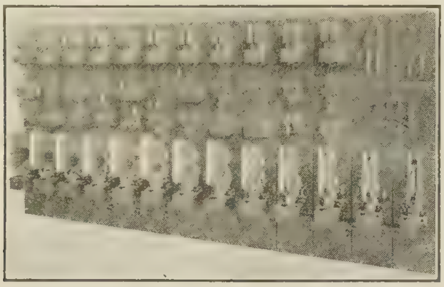


Fig. 6—Automatic Control Panel for a 6000-Kw. Adjustable-Ratio Frequency Converter

Power factor correction is furnished by the main induction machine supplying a quadrature component of voltage in its secondary circuit. This quadrature component is obtained from the armature of the regulating machine by exciting its power factor field from a third set of brushes located on the commutator of the a-c. exciter. See Fig. 3.

By use of a series or so-called "bulging transformer," as shown in Fig. 3, automatic power-factor correction is obtained to compensate for the change in wattless kilovolt amperes that would ordinarily occur on the induction machine with change in load.

Operating Characteristics

Fig. 5 shows the output of the regulating machine for different combinations of slip on the induction machine and unity power-factor load on the main induction unit.

When the regulating machine is operating as a motor, the secondary power that would be lost in the resistor method is transferred through the regulating set back into the line. When the regulating machine is operating as a generator, power is taken from the machine lines and transferred through the regulating set to the rotor of the induction machine.

Load Control

Load on the 6000-kw. adjustable-ratio frequency converter described may be held either by hand or automatically. The control switch is connected to the small motor which shifts the brushes on the a-c. exciter commutator. For automatic load control, a load relay is provided which may be set to hold any load desired within the operating range.

Starting

Control equipment is furnished which permits automatic starting of the set from the 25-cycle end. The operator starts the sequence of operation by merely pulling a control switch located on the switchboard. Fig. 6 shows the starting panel.

Protective Features

Protective features are provided against a-c. undervoltage, over-speed, over-load, and excessive bearing temperature, and insure that the a-c. exciter commutator brushes are in the neutral position before starting.

The other 6000-kw. frequency-converter sets are very similar to the Rochester 6000-kw. set which has been described in considerable detail. Some have increased frequency range, and provision for increased power-factor correction in the 25-cycle equipment.

The Devon 5000-kw. sets are different in several details from the 6000-kw. sets described. In this case, the regulating machine is connected to the shaft of the main set, which makes an economical arrangement. Furthermore, on this unit provision is made for automatic power-factor control, as well as automatic load control, so the bulging transformers were omitted. Further simplification was made in the Devon sets by omitting the third set of stationary brushes on the commutator of the a-c. exciter, and exciting the power factor field of the regulating machine from one of the sets of movable brushes. Also, in this case, no resistor was furnished in the primary circuit of the main induction machine, because of the lower induced secondary voltage in this unit.

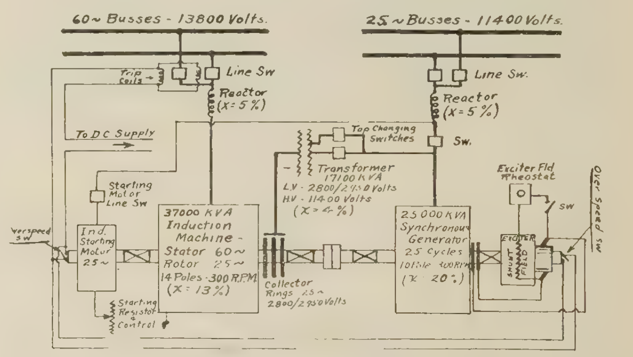


Fig. 7—Diagram of Connections for 35,000-Kw. Fixed-Ratio Induction-Synchronous Frequency Converter

Fixed Ratio Induction-Synchronous Type

A paper[3] has been written which covers in much

3. *A 35,000-Kw. Induction Freqency Converter,* by O. E. Shirley, A. I. E. E. Trans., 1924, Vol. XLIII, p. 1011.

detail the design, theory, and operation of the fixed-ratio induction-synchronous type of set.

Fig. 7 shows a diagram of connections for a 35,000-kw. set, which consists of an induction and a synchronous machine.

A portion of the power transfer is made through the shaft of the unit in the ordinary way and the remainder of the power transfer is made electromagnetically through the induction machine by connecting its stator to the 60-cycle system, and its rotor to the 25-cycle system.

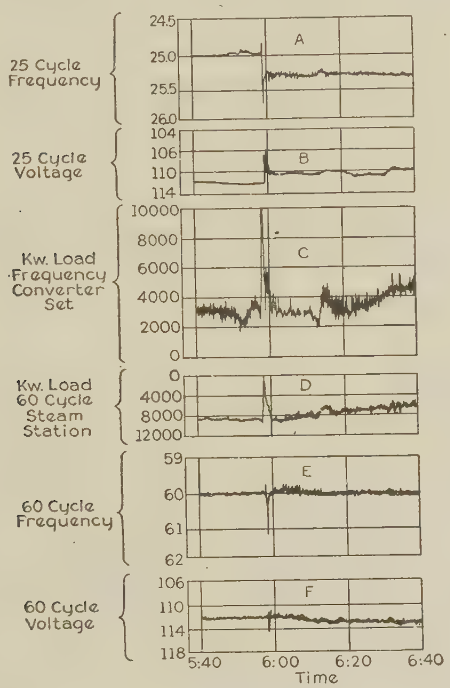


FIG. 8—CHART RECORDS OF A DISTURBANCE CAUSED BY SHORT-CIRCUIT ON 25-CYCLE SYSTEM

System tied to 60-cycle system by two 6000-kw. adjustable-ratio induction-synchronous frequency changers. Chart shows load on one set.

Full load may be transferred through the set in either direction with unity power factor input. The magnetizing current of the induction machine is supplied through its rotor from the synchronous machine, which is designed to furnish the necessary reactive kv-a. for this purpose.

The induction-synchronous type of set has a rather limited field of application, being used principally to furnish power to small loads where the frequency required is different from the frequency of supply.

The fixed-ratio induction-synchronous type of frequency converter has a limited field of application also, its principal use being in large cities where synchronous converters supplied with a-c. power of two different frequencies are to be tied together on the d-c. side. With this type of set, the two a-c. systems are tied together through the same magnetic field; therefore the tie functions practically as a cable tie.

Operating experience shows that in the majority of cases interconnected systems may be so operated that systems of different frequencies may be connected together by synchronous-synchronous frequency converters with no great inconvenience. The adjustable-ratio frequency converters have the advantage that they may ride through system disturbances with less need of disconnecting the two systems.

There are particular applications in which the cost of an adjustable ratio frequency converter may be warranted. Frequency converters of this type are well adapted to connect large central station power systems to industrial or railway systems where the industrial load or railway load may cause considerable frequency fluctuations. Another application would cover cases where the extra cost of the adjustable frequency ratio type will be warranted from the standpoint of being able to control the load at the set itself without need of making adjustments on prime mover governors.

CHART RECORDS

Chart records given in Figs. 8 and 9 show how well frequency converter sets of the adjustable ratio type operate during system disturbances. The charts in question were taken at Rochester in connection with the 6000-kw. adjustable-ratio frequency converter sets previously described.

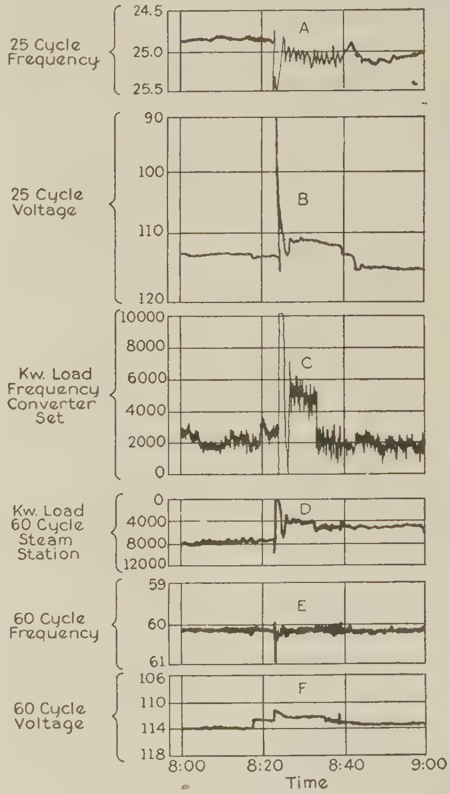


FIG. 9—CHART RECORDS OF A DISTURBANCE CAUSED BY A VERY SEVERE SHORT-CIRCUIT ON 25-CYCLE SYSTEM

System tied to 60-cycle system by two 6000-kw. adjustable-ratio induction-synchronous frequency changers. Chart shows load on one set

In each case the system disturbance was caused by a short circuit on the 25-cycle system.

The disturbance recorded in Fig. 9 was much more severe than the disturbance recorded in Fig. 8.

The fact that the adjustable ratio frequency con-

verters rode through these disturbances as well as they did, speaks very well for their operation. It is very probable that a synchronous-synchronous set would have dropped out of step during the disturbances shown.

The author wishes to express his appreciation for the cooperation given by E. K. Huntington of the Rochester Gas & Electric Co. regarding the chart records described, and to acknowledge the general assistance given by Messrs. J. I. Hull, P. W. Robinson, and O. E. Shirley.

Abridgment of

Design Studies for Gould Street Generating Station

BY F. T. LEILICH[1], Member, A. I. E. E.
C. L. FOLLMER[1] Non-Member
and
R. C. DANNETTEL[1] Non-Member

Synopsis.—*Developments in the central station art have been so rapid within the last few years that many of the recent outstanding stations differ considerably in the major elements of design.*

In the following are briefly outlined high points of the analyses upon which the principal features of the Gould Street station design were based.

THIS paper covers briefly the various studies and investigations upon which the Gould Street station design was based. Load studies clearly showed the need of additional $62\frac{1}{2}$ cycle generating capacity in 1927. As a result, a single-unit station, of approximately 35,000 kw., was authorized. The major features to be settled before equipment specifications could be prepared and detail design work started were: Steam pressure and temperature; number and size of steam generators; type of firing—stokers or pulverized fuel; heat cycle or working heat balance; the most economic design of condenser; auxiliary drive—electric or steam.

Steam Pressure and Temperature

The general trend of pressure and temperature was upward, as shown by Fig. 1, which was plotted from the specifications of 85 stations. Operating records of other plants were studied and most of the new stations visited, and the design and operating problems discussed with the engineers. Essentially, the problem was to select a pressure and temperature that would result in maximum reliability and minimum total costs.

Operating experiences with pressures up to 400 lb. and total steam temperatures up to 725 deg. fahr. were sufficiently extensive to show clearly that from the standpoint of reliability and operating difficulties these limits could be adopted for a conservative design. To obtain concrete figures showing the effect of pressure on costs and economy, detailed estimates based on a 40 per cent capacity factor, of a 250-lb.—700-deg. fahr., and a 400-lb.—700-deg. fahr. station were made. It is interesting to note that the estimated cost per kw. of the 250-lb. station was 4 per cent greater than for the higher pressure, and the over-all economy of the 400-lb. installation was six and one-half per cent better. Studies of relative costs of 600- and 700-deg. fahr. equipment showed that the improved economy of the higher temperature would justify the slightly increased cost of superheaters and added thickness of high temperature insulation.

A maximum drum pressure of 450 lb., with 725 deg. fahr. temperature at the superheater outlet was selected.

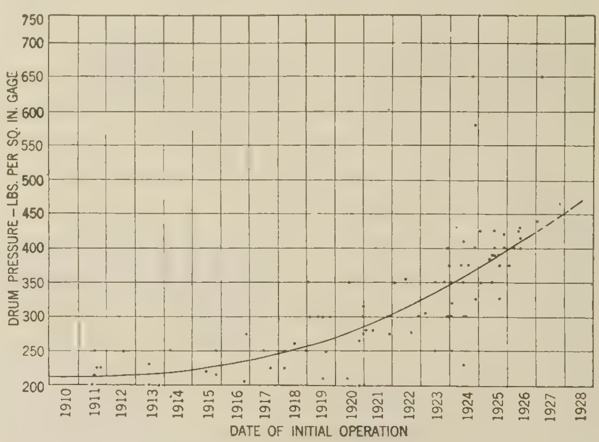


Fig. 1—Trend of Boiler Drum Pressure in Power Plants

This corresponds to 390 lb., 700 deg. fahr., at the turbine throttle. This temperature and pressure was selected after numerous conferences with the engineers of the various manufacturers and at the same time the possibilities of extension, using 1200 to 1500 lb. at the throttle of high-pressure turbines, exhausting at approximately 400 lb., into existing mains, were not overlooked.

Number and Size of Steam Generators

The boiler specifications called for working pressure in the drum of 425-lb. gage and total heating surface

1. With the Consolidated Gas, Electric Light & Power Co., Baltimore, Md.

Presented at Regional Meeting of District No. 2, of the A. I. E. E., Baltimore, Md., April 17-19, 1928. Complete copies upon request.

of 26,500 sq. ft. The contract as awarded specified operation up to 520,000 lb. of steam per hr., which corresponds to approximately 550 per cent of rating, based on the total boiler and furnace heating surface. The trend of fixed and operating cost records of representative stations showed fixed costs as an increasing percentage of total costs and it was obvious that operating and kilowatt investment costs would be reduced if a small number of large steam generating units designed to operate efficiently over wide ranges of rating could be used.

Load and operating conditions indicated that the turbo generator units should have capacities of from 30,000 to 40,000 kw. each. The ultimate capacity of the station was tentatively set at four units, or approximately 140,000 kw. Estimates of investment costs for both equipment and structure showed distinctly lower costs for a design based on one boiler per turbine. With the cross-drum type of boiler, which was preferred by the engineers, additional heating surface could be economically obtained by increasing the length of the tubes and making the tube bank the maximum width consistent with drums having no girth seams.

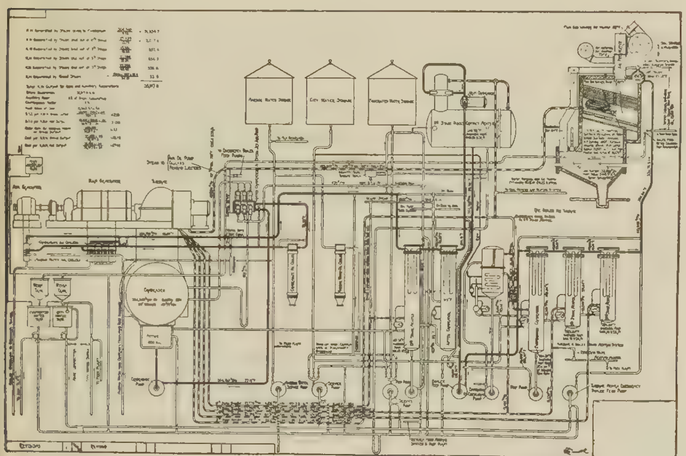


Fig. 2—Flow Sheet Representing Full-Load Operation with Four-Stage Bleeding and 29-in. Vacuum at Turbine Exhaust

Type of Firing

Many of the newer plants were using pulverized fuel, but it was not obvious that the advantages of this type of firing were such that it should be adopted without careful study. Proposals on stokers and pulverized fuel were obtained and economic set-ups, covering both fixed and operating costs, prepared. Although pulverized fuel investment costs were higher, when the merits of the two systems—tangible and intangible—were carefully considered it was finally decided to adopt the central system of pulverized fuel firing.

Heat Cycle

A primary consideration was the selection of a heat cycle that would result in the lowest total cost, when both fixed and operating charges are included. Calculations showed that four-stage bleeding and air preheating would yield a greater return on investment than two or three bleeding stages combined with an economizer and preheater with the further advantage of an approximate increase of 10 per cent capacity at only a slight drop in economy when operating under peak or emergency conditions with the two top-stage bleeders shut-off. The foregoing advantages and an economy increase of approximately 0.45 per cent by the use of four stages as compared to three led to the adoption of the four-stage bleeder cycle.

Fig. 2 is a flow sheet showing the station heat balance for full load generation operating under 29 in. of vacuum.

The normal course of the condensate leaving the hot well pumps is in order through the steam jet air pump inter-condenser, oil cooler, generator air cooler, tenth stage heater, after-condenser, eighth stage deaerating heater, boiler feed pump, evaporator condenser, fifth stage heater, and third stage heater to the boiler feed mains at a final temperature of 365 deg. fahr. By-passes are provided individually for the oil cooler and the generator air cooler bank, and as a group for the tenth stage heater and after-condenser, and again as a group for the evaporator condenser and top-stage heaters. Drips are cascaded from the top stage heaters to the evaporator condenser from which they are pumped into the condensate line leading to the eighth stage heater. Drips are cascaded also from the after-condenser to the tenth stage heater from which they are pumped into the condensate line leaving the tenth stage heater.

Table II shows the calculated over-all B. t. u. per kw.-hr. net station send-out. This is based on one boiler per turbine, auxiliary power 6 per cent of gross generation, over-all contingency factor 4 per cent, and throttle conditions 405 lb. absolute, 700 deg. fahr.

TABLE II
B. T. U. PER KW. HR.—NET STATION SEND-OUT

Load	28-in. vac.	28.5-in. vac.	29-in. vac.
35,000 kw.	15,562	15,291	15,138
25,000 kw.	15,103	14,707	14,356
15,000 kw.	16,855	16,313	15,695

A turbine designed for non-bleeding operation was modified for bleeding conditions. By increasing the steam flow areas in the first stages, it was possible to admit sufficient steam for bleeding and still use the last stages as effectively in normal operation as for non-bleeding design. The non-bleeding machine was designed for 29-in. vacuum, but with the lower average vacuum of less than 29 in. expected at this installation, a greater quantity of steam is passed through to the condenser without increasing the leaving losses from the last stage and by reason of the power generated by this increased flow, together with that generated by

the additional steam admitted for withdrawal at the bleed points, the capacity of the turbine is increased. A change from eleventh stage bleed-point to tenth stage gave an increase of 0.25 per cent in station economy.

Condenser

The average injection water temperatures throughout the year and the heat rejected to the condenser under various loads and exhaust conditions were the bases for the selection of the economic amount of condenser surface. The method of analyzing turbine performance is described in the N. E. L. A. Prime Movers Committee Report on Turbines, December, 1926. The curves, (Fig. 4), show the relation between injection water and exhaust steam temperatures for different load conditions and different areas of condensing surface. From the load duration estimate, injection water temperatures,

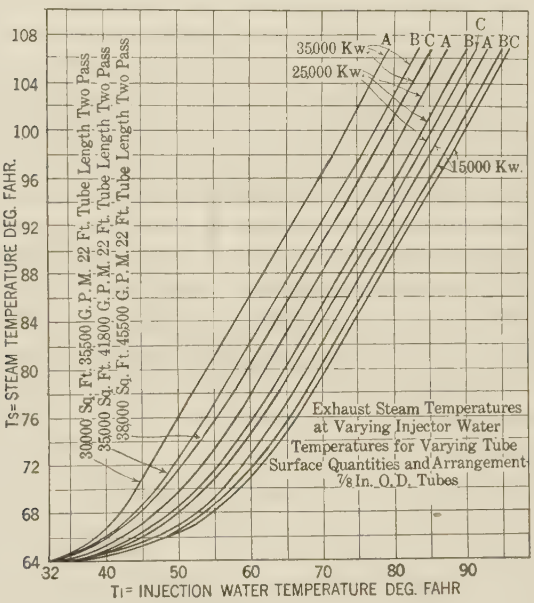


Fig. 4

and Fig. 4, the relative fuel economies of the different size condensers were determined. It was found that 30,000 sq. ft. was about the maximum justifiable surface. This corresponds to 0.833 sq. ft. per kw. of generator capacity.

It was essential that special effort be made to improve the purity of the condensate over that which ordinarily obtains in tide water plants, otherwise the continuous operation of the boilers at high ratings would be seriously hampered. The point of attack was the leakage at the packed joints of the tubes. Fixed tube sheets with tubes rolled in at both ends had been used in the Navy, and it appeared feasible to adapt the principle to power-plant service. In tests made with an 18-ft. tube set up with the slight upward bow of 1½-in. at the center of its length between fixed plates, it was found that repeated reversals through it of water sufficiently hot and cold to give it the expansion between plates that would be encountered in service, produced no change in the structure of the metal of the tube, and the joints in the tube sheets remained tight. The tube was restrained in its vertical motion by tube support plates. The shape of the expanded tube resembled a sine curve of about one and one-half cycles. The axial thrust of the tube against the sheets was as high as 425 lb., maximum, and at first it appeared that the staying of the sheets would be a difficult problem. The tube sheet layout shown in Fig. 5, in which all stay-bolts are omitted and tubes rolled at both ends into fixed sheets, was adopted.

The manufacturer agreed to construct a condenser in accordance with this design with the provision, however, that the purchaser assume all responsibility for its success or failure.

Auxiliary Drive

Electric drive was selected for the auxiliaries. Some of the factors influencing this decision were:

1. Elimination of small high-pressure steam lines and exhaust lines.

2. Easier control of the heat cycle, since the steam requirements of turbine driven auxiliaries are not necessarily a direct function of the generator output.

3. Relatively high economy of shaft-driven generators as compared to individual turbine drive. The steam per kw-hr. requirement for the auxiliary generator is the same as that of the main unit.

4. Flexibility and reliability of electric motors and their control.

The general tendency in auxiliary drive is shown in Table III, in which 2300, 440, and 220 volts were the prevailing a-c., and 250 volts the prevailing d-c. potentials. Alternating current had been used in the greater number of installations and has the following advantages:

1. Available up to a capacity far in excess of auxiliary requirements, if transformers are used.

2. Relatively low costs of motors and control for applications with small ranges of speed control.

3. Absence of commutators (excepting brush shifting motors) and elimination of sparking, which is highly desirable in a pulverized fuel installation.

The selection of the most economical secondary voltage required extensive calculations and estimates in which were considered motor, control equipment and installation costs, for voltages of 2300 and 440 and speeds from 575 to 1750 rev. per min.; also space requirements and such intangibles as reliability, ease of inspection, etc.

A voltage of 2300 showed a saving in copper for long runs, but was considered undesirable because of the impracticability of inspection of the control equipment under load. The higher voltage motors are standard only in the larger sizes, and their use necessitates a low-voltage supply for the motors below about 50 hp.

From the standpoint of the motor cost alone the 23,000-volt equipment was economically advantageous

TABLE III
THE MAIN AUXILIARY CHARACTERISTICS OF CENTRAL GENERATING STATIONS

Year of initial operation	Auxiliary voltage			Boiler feed pump drive			Circulating pump drive		
	High 3000-2200	Medium 660-440	Low 250-110	Turbine	Turbine and motor	Motor	Turbine	Turbine and motor	Motor
Other years	0	1	2	2	1	0	3	0	0
1911	2	2	0	2	2	0	1	2	1
1912	0	1	0	1	0	0	0	1	0
1913	0	3	0	0	3	0	1	2	0
1914	0	1	0	0	1	0	0	0	1
1915	0	2	2	2	2	0	1	2	1
1916	1	1	0	1	1	0	1	1	0
1917	0	2	0	1	1	0	0	1	1
1918	1	3	0	2	2	0	0	2	2
1919	2	5	0	4	2	0	1	3	2
1920	3	0	1	3	3	0	2	2	2
1921	2	3	0	3	2	0	0	3	2
1922	2	0	1	0	3	0	0	1	2
1923	6	3	0	4	5	0	0	3	6
1924	12	3	0	6	8	2	0	2	12
1925	8	5	0	0	11	2	0	2	11
1926	6	0	0	1	4	1	1	1	4
1927	1	1	0	0	2	0	0	0	2

NOTE:

1. Since practically every station has electrically-driven auxiliaries and all use alternating current except for a very small portion of the axuiliaries, such as stokers, it was assumed that all auxiliaries are driven using alternating current.
2. In cases where more than one voltage is used for the auxiliaries, it was assumed that the larger auxiliaries using the major portion of the auxiliary power, employed the higher voltage.
3. The fans were almost without exception driven by motors.
4. Boiler feed pumps listed under turbine and motor drive are usually motor-driven with turbine-driven stand-bys.
5. The numbers under each heading indicate the number of stations in that class for the stated year of initial operation.

only for the larger size motors. For the range of sizes to be used in this station, the 440-volt equipment was less expensive in practically every case.

Estimates of the cost of distribution cable showed that the cost per ft. is about equal at 100 hp.; below this, the cost advantage was in favor of the 440- to 460-volt. Cable costs were based on 440-volt lead covered cable with 600 volt insulation, and 2300-volt lead covered cable with 4000-volt insulation. When motor, control, and cable costs were added to the value of the space requirements, the 2300-volt system proved to be more expensive than the 440-volt. The final selection was 460 volts, three-phase, 62½ cycles.

For the auxiliary circuits it was desirable that oil breakers be eliminated and contactors or carbon breakers be used. It was obvious that the circuit-interrupting devices should be of sufficient capacity to handle short circuits, and in order to arrive at a basis upon which to prepare specifications, a number of tests was carried out. The problem was put up to the manufacturers to furnish standard size contactors and circuit breakers rated up to 2000 amperes, which, under test, would handle repeated short circuits of not less than 20,000 amperes at 440 volts, 25 cycles, as the tests were to be made on 25 cycles. The contactors tested would not handle these currents, as after one or two operations the contacts had a tendency to "freeze." As a result of these tests, several of the manufacturers made modifications to their equipment, after which the contactors stood as many as five shots with practically no damage. With slight modifications, several of the standard carbon breakers handled about 20,000 amperes quite successfully. One feature insisted upon was that the breakers be "non-closeable" on short circuit, or trip free and although the contactors handled the short circuits as well as the breakers, it was decided that the breakers were preferable, for the reason that in case of failure of the holding coils, the circuit breakers would not drop out.

A control voltage of 250 volts, d-c., was used to eliminate the effects of a-c. disturbances on control

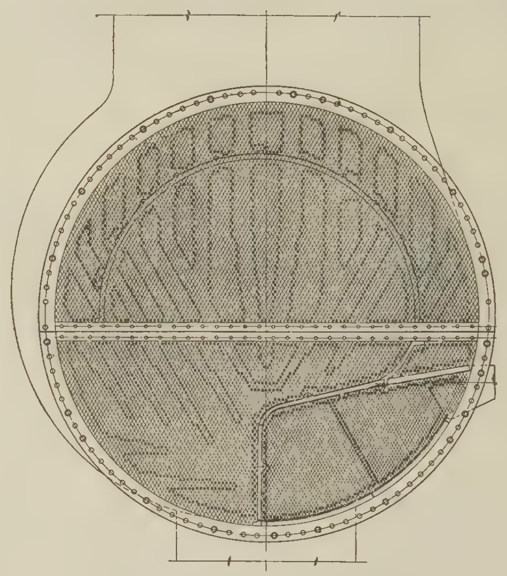


FIG. 5—INLET END TUBE SHEET LAYOUT FOR 30,000-SQ. FT. CONDENSER. (NOTE QUESTION MARK BAFFLE FOR GUIDING WATER FROM AIR COOLER TUBE SURFACE TO OUTSIDE RING OF TUBES IN SECOND PASS

apparatus and to insure quiet and more reliable operation of the contactors.

Auxiliaries were divided into two classes—essential, or those necessary for the uninterrupted operation of the turbine and boilers, and non-essential, or those such as pulverizing machinery—coal-handling plant and other equipment, a temporary shut-down of which would not interfere with the operation of the main unit and boilers. The essential auxiliaries are supplied with energy from the shaft-driven alternator, the non-essentials from a bank of three 1000-kv-a., O. I. S. C. transformers. The arrangement is such that in the event of failure of the shaft-driven alternator, the load is automatically transferred to the transformer bank. All auxiliaries are 460-volt, three-phase, 62½-cycle, except the turbine room crane and the pulverized fuel feeder motors. These are supplied from motor-generator sets, one running from the essential auxiliary bus, the other arranged to transfer the load automatically

onto the transformer bank bus in the event of failure of the first motor-generator set.

To reduce the voltage drop in the 460-volt bus, the copper in each phase was run in interleaved sections.

Combustion Control

A study of automatic combustion control was made, and calculations based on the guarantees and a study of performance in existing plants indicated that the increase in monthly efficiency would justify the cost.

On account of the wide range of speeds—8 to 1 on both forced and induced draft fans—double winding, six-phase, secondary slip-ring motors were specified. A large number of speed points were necessary, and special control equipment consisting of drums and a motor-operated transfer switch for changing from the high- to the low-speed connection on the motor were installed. An excessive number of contactors would have been required to give the number of speed points specified. Also the cost of the control equipment using drums was appreciably less than for contactors.

Abridgment of

220-Kv. Transmission Line for the Conowingo Development

BY P. H. CHASE[1]

Member, A. I. E. E.

***Synopsis.**—Current from the Conowingo plant is carried fifty-eight miles to the Plymouth Meeting Substation of The Philadelphia Electric Company over two 220-kv. single-circuit steel-tower transmission lines. These lines are carried on a right-of-way which provides space for a third future line. The conductors are 795,000-cir. mil steel-reinforced aluminum. Each circuit is shielded by two 183,600-cir. mil aluminum steel-reinforced ground wires. The insulator strings consist of 14 high-strength units in suspension position and 16 units in strain position. Conductors and ground wires are carried in a new type of slip clamp in order to decrease the unbalanced longitudinal stresses on the towers in the event of wire breakage. In general, foundations are of the earth grillage type. The tower design includes a number of novel features, among them the use of combination extensions to flexibly meet the varying topographical conditions, and the narrow waist immediately below the basket.*

FOR the ultimate development, the 58-mi. transmission line to Philadelphia from the Conowingo hydroelectric plant on the Susquehanna River, will consist of three 220-kv. single-circuit tower lines, each circuit supported in horizontal configuration. For the initial development two of the tower lines have been constructed.

The location of the Philadelphia terminus of these lines, the Plymouth Meeting Substation, approximately 15 mi. northwest of the center of Philadelphia, was determined by a number of factors, among them the practicable transmission routes into the main 66-kv. transmission system of The Philadelphia Electric Company, and the 220-kv. transmission line routes for interconnection with Pennsylvania Power and Light Company and Public Service Electric and Gas Company of New Jersey.

The location of the right-of-way is shown in Fig. 1. After determination of the general location of the right-of-way by ground reconnaisance, an airplane map was made of a strip from 1½ to 3 mi. wide, to a scale of 1000 ft. to the inch. The airplane maps were used as a basis for the final location of the line and the determination of property owners and their holdings, from which final options were prepared for negotiation

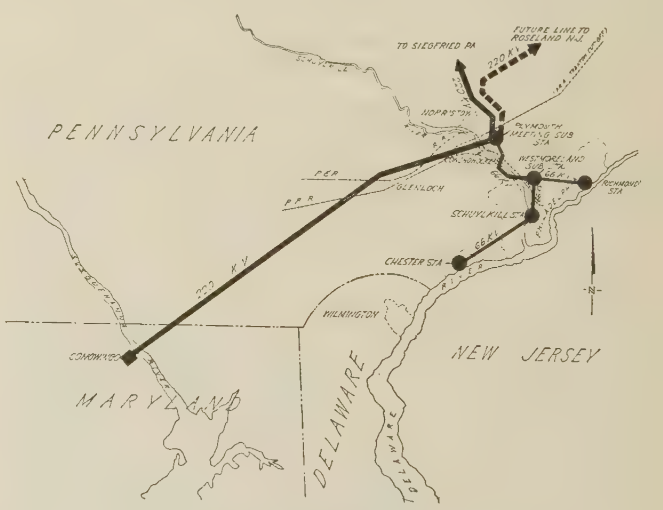


Fig. 1—Route of Line

with owners of record. All these steps were taken prior to any negotiations or survey activities in the field. The right-of-way was secured on the principle of easements, being preferable to purchase in "fee simple."

1. Engineer, Transmission & Distribution Division, The Philadelphia Electric Company.

Presented at the Baltimore Regional Meeting of A. I. E. E., Dist. 2, Baltimore, Md., April 17-20, 1928. Complete copies upon request.

Basis of Design

The following types of towers were used on the line:

Type A—Standard suspension tower, suitable for angles up to 1½-deg., 1100-ft. span.

Type B—Railroad crossing and angle tower, suitable for crossings, angles up to 6 deg., and tangent spans up to 2000 ft. This type, with a special top extension, was used for transpositions.

Type C—Angle tower, suitable for angles from 6 to 15 deg., and spans up to 1100 ft.

Type D—To be used for angles 15 to 60 deg., dead ends, and tangent spans up to 2500 ft.

In general, the line is designed to withstand a climatic loading of one-inch ice, but for unbalanced longitudinal load on the Type-A standard suspension tower, a tension in the conductor was taken corresponding to a load of ½-in. ice, it being obviously uneconomic to design for more severe conditions. Therefore, in order to

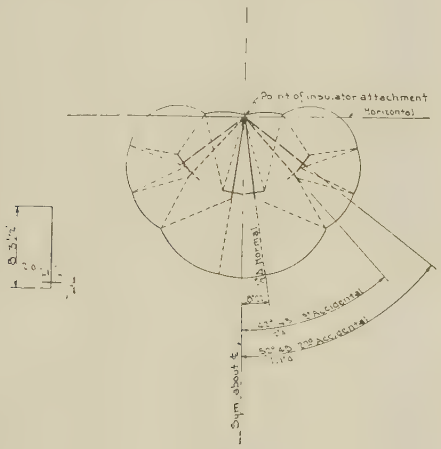


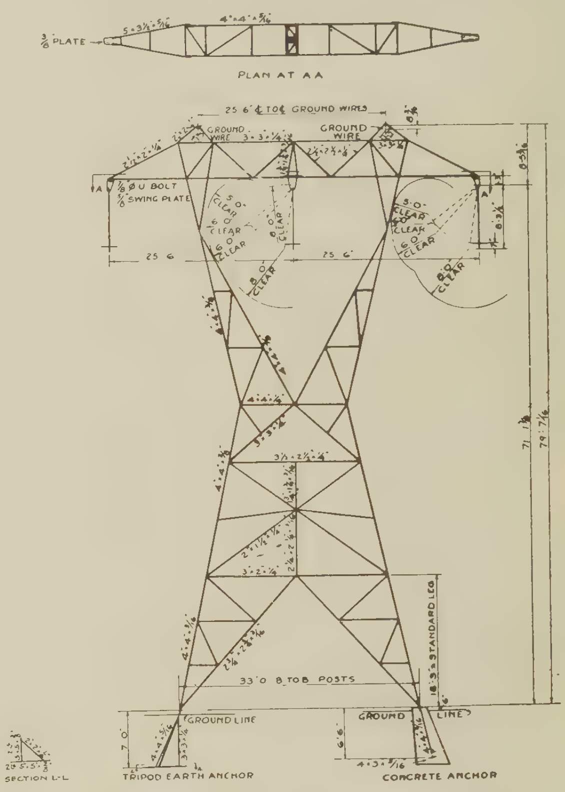
Fig. 2—Clearance Diagram for Type-A Towers

minimize the stresses to which the tangent towers might be subjected under extraordinary conditions, a clamp of the releasing type was developed, to limit the maximum unbalanced longitudinal load on the tower to approximately 10,000 lb. Heavier ice loading was given consideration in the design of all types of towers for certain check conditions.

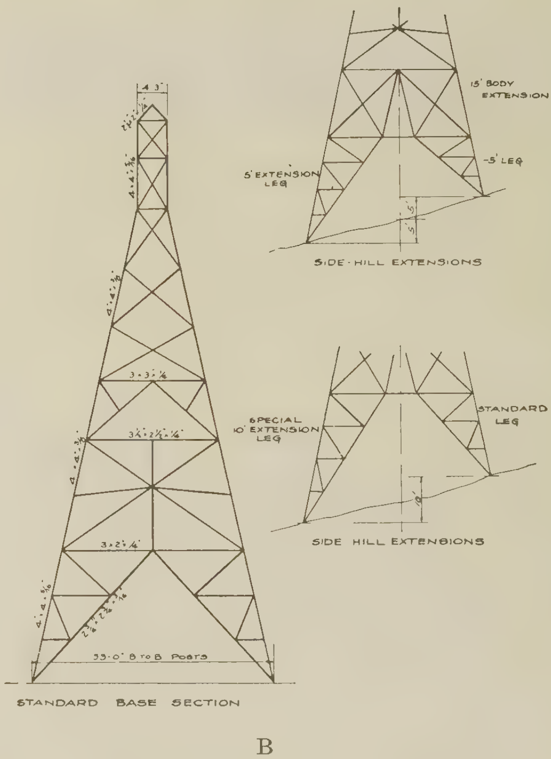
The design loads for the towers were calculated under the various assumed conditions of ice and wind for longitudinal, vertical and transverse loading. These figures were increased by safety factors, thus giving maximum loads which the structural work of the towers was designed to withstand.

The Type-B tower was designed to meet the requirements of General Order No. 13 of the Public Service Commission of Pennsylvania, which permitted its use for long tangent spans under non-crossing conditions.

The clearance diagram for the Type-A standard suspension tower is shown in Fig. 2. The clearance diagram was based on an ultimate string of 16 units and an arc control device having a probable transverse dimension of 24 in., and so located in the tower as to result in a normal clearance of 8 ft., a first accidental clearance of 6 ft. and a second accidental clearance of



A



B

Fig. 3—Type-A Suspension Tower

5 ft. The first accidental clearance was on the basis of an 8-lb. wind, and the second accidental clearance on a 12-lb. wind, both without ice.

The length of span, height of tower, strength class of insulators, and characteristics of conductor must all be considered as a group, in order to determine the most economical combination and still maintain the most reliable service conditions obtainable. The size of conductor was determined by the electric loading conditions. This resulted in a conductor of 795,000-cir. mil aluminum, steel-reinforced with a 40 per cent steel core, approximately 1¼-in. over-all diameter, which satisfied the corona requirements.

The conductor diameter being thus determined and the ground clearance controlled by safety conditions, the over-all economics of tower height and span length were considered by studying various heights of towers, and for each height, increasing or decreasing the span to meet the catenary of the wire under consideration. The minimum ground clearance was 29 ft. 6 in.

Towers and Foundations

Fig. 3 shows the assembly of the Type-A suspension tower. It is designed for one three-phase 220-kv. circuit,—the conductors in a horizontal plane with a separation of 25 ft. 6 in. Two ground wires are carried approximately 16 ft. above the plane of the conductors and midway between them. The lower section of the tower is square, so that the batter of the legs is the same in any face, resulting in a pyramidal section up to a point about 20 ft. below the conductors, where the sides flare outward to provide the necessary clearance for the middle conductor.

Particularly on account of the size of the base, which is about 35 feet square, horizontal members close to the ground line are undesirable. To avoid this, the lower section is composed of four legs, each of which is independent, and may be made of any suitable length for small extensions and for uneven ground conditions. The standard legs are about 18 ft. in height, resulting in an 80-ft. tower, but special legs, both 5 ft. shorter and 5 or 10 ft. longer, have been used. As the connections are standard, any of these legs may be used on any one of the four corners of the tower.

For extensions greater than 10 ft., an additional section is inserted in the tower above the legs. By the use of the 15- or 30-ft. body extensions, the height of the tower may be increased by 5-ft. intervals to 125 ft.

Several new features of economic value are embodied in the tower. Maintaining the square horizontal section to as great a height as possible,—(to the waist line)—equalizes the distribution of the torque stresses in each of the four faces of the tower below the waist. The unbalanced horizontal shear at the foundation is reduced to a minimum by fixing the legs at an angle such that, if extended above the waist line, they would intersect at the center of gravity of the loads. The fact that the stresses are mainly in the tower legs permits very long equal or unequal leg extensions of the same size angle.

For foundations, two designs were used; for normal line construction, a structural steel tripod anchor extending 7 ft. below ground; for special construction, a concrete foundation into which is placed an extension of the main leg angle. These two anchors for the Type-A suspension tower are also shown in Fig. 3.

A B C

Fig. 4—Insulator Strings and Clamp

Conductors and Ground Wire

Considerable study was given to the characteristics of the steel-reinforced conductor, and the operating experience from all the major companies was carefully considered with special reference to eliminating troubles which have arisen in some cases from vibration of the conductor. Considerable investigation work has been

done, both by The Philadelphia Electric Company and the Aluminum Company of America in attempting to solve this problem. Investigation work indicated that when a metal is not under an appreciable initial strain it can withstand vibration practically indefinitely, but that its ability to withstand vibration decreases as the initial strain increases. This principle also applies to the aluminum strands of a cable.

Further investigation work on the modulus of elasticity of the finished cables has shown that the modulus depends upon the maximum tension which the cable has withstood. This is due to the fact that as the cable is stretched under tension the aluminum strands first share the strain with the steel until they are stretched beyond their elastic limit, at which time they take a permanent elongation. As the strain on the cable is released, the steel core, due to its greater elasticity, begins to pick up the strain and relieve the aluminum strands. This indicates the advisability of pre-stretching the cable. This pre-stretching secures two advantages, the first of which is indicated above in obtaining the reduction of the stress in the aluminum strands, and the second is that it establishes the modulus of elasticity of the cable, so that its characteristics, and consequently the sag, will not vary when the cable is subjected to a heavy ice and wind loading.

In a cable having a content of about 40 per cent by weight of steel, stress-strain curves show that after pre-stretching there is practically no tension in the aluminum strands under the ranges of temperature which usually exist at those times when vibration is most severe, namely, in fairly cold weather and with light winds. Experience has shown further that in practically every case where trouble has been experienced with broken strands, the steel content has been in the neighborhood of 25 to 30 per cent, and no strand failures with the 40 per cent content have been reported.

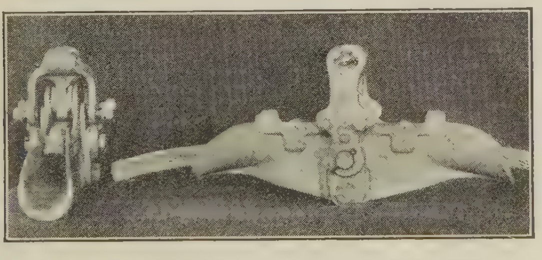


Fig. 5—Release Clamp

In selecting the ground wire, it was concluded that it should be of the same general nature as the conductor, so that both materials would act in the same manner in unloading ice coatings; also that they should have approximately the same sag and swing characteristics. As an aluminum steel-reinforced cable was selected for the conductor, the same type of cable was selected for the ground wire.

Consideration was given also to securing a ground wire having sufficient current-carrying capacity to meet the requirements of lightning protection, and also to distribute any currents which might flow into the tower under the condition of an insulator flash-over. It would have been possible to meet the above requirements with an all-steel galvanized cable, but a layer of aluminum strands outside the steel core has a preservative effect on the galvanizing, and consequently a cable with a steel core of approximately the same size as the conductor and carrying two layers of aluminum strand, was finally selected.

Insulators and Hardware

The line is insulated with high-strength 10-in. disk insulators with 5¾-in. spacing. The design provides for an ultimate of 16 units for single and double suspension strings and 18 units for triple dead end strings. The initial installation is with 14 units in suspension and 16 for triple-yoke strings, with a spacer link next to the tower having a length equal to two insulators, so that the conductors in every case are in the ultimate position.

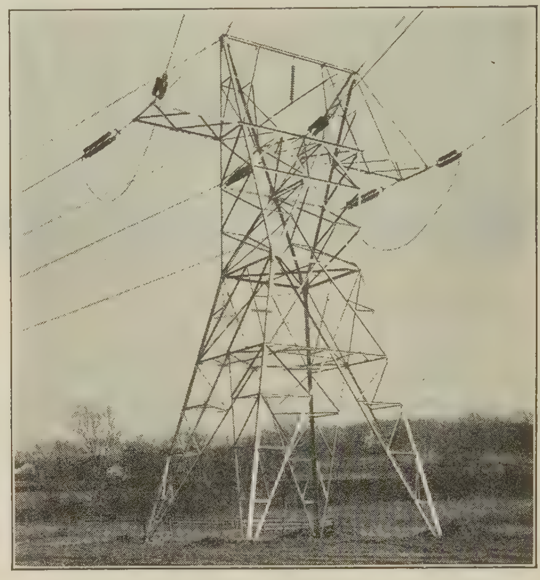


Fig. 6—Dead-end Tower and Jumper Construction

The single, double and triple string assemblies are shown in Fig. 4.

Except at points of special construction, the conductor and ground wire are carried in a releasing type of clamp, shown in Fig. 5. For special suspension construction, a non-releasing clamp was used. Both clamps are of galvanized cast steel. In order to reduce the vibration-reflecting characteristics of the clamp they are free to swing in a vertical plane about an axis intersecting the axis of the conductor.

The releasing clamps are so designed that an unbalanced pull, which will produce a longitudinal swing of 20 deg. of the insulator string, will completely release the clamping mechanism. The wire is then held only by the friction in the saddle of the clamp. By the use of these clamps the longitudinal pull from a broken wire

is restricted to a small fraction of the strength of the wire and under heavily loaded conditions should not exceed 5000 lb. This results in longitudinal tower stresses considerably less than if the release clamp were not used.

On the dead-end towers, the middle conductor is carried above and through the center of the tower, as shown in Fig. 6. The great distance from outside to

Fig 7—Susquehanna River Crossing

outside of insulator string, for the center conductor made it impossible to support the jumper with a suspension string in the center and avoid the stranded conductor sagging to such a point as to decrease the clearances below safe limits. In order to maintain an economical design of tower top, recourse was had to

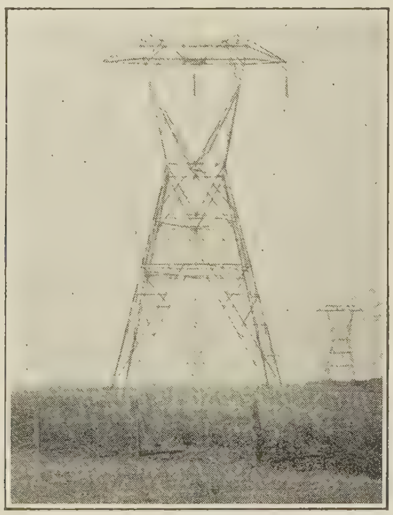


Fig. 8—Typical Line Construction

carrying the stranded aluminum conductor in a 3-in. aluminum pipe, 24 ft. long. To each end was attached an aluminum reducing coupling carrying a 3-ft. extension of 1½-in. aluminum pipe from the end of which the conductor dropped free into the 90-deg. compression aluminum dead-end fitting.

Provision has been made for the attachment of arc control devices. A decision has been made to install some form of arc control device in the near future.

The transmission lines leave the power house on the west bank and are carried to the east bank in two spans —1450 and 2200 ft., respectively. The intermediate towers are located on an island in the channel of the river, and act as a dead-end and single tower, greatly diminishing the stresses on the roof structure. These towers are shown in Fig. 7. They are 228 ft. high, (above the foundations), weigh 113 tons each, and have a base spread of 60 ft., supported on concrete piers 20 ft. above ground, with a bridge-type walk-way interconnecting the piers.

Fig. 8 shows typical tangent line construction.

MORE POWERFUL CATHODE RAYS

Remarkable and rapid advances in synthetic chemistry are promised through the use of high-speed electronic bombardment, which is made available by the Coolidge cathode-ray tube. High-speed electron bombardment provides a new and powerful instrument for upsetting the stability of many types of molecule and atom, transforming them to other types of stable compound, thus providing a rapid and efficient process for replacing old and expensive methods, and in many cases offering a means for transformation hitherto unknown or thought to be impossible. High-velocity cathode rays have long been available within the confines of the vacuum tube, but these conditions do not lend themselves readily to the chemical transformations referred to.

The Coolidge high-voltage tube provides a means for bringing the cathode rays through a window into the open, where different materials may be readily subjected to their influence. Announcement now comes from Germany that Prof. H. Plauson has effected such improvements in the Coolidge tube as to make possible a very great intensification of ionic activity. The improvements consist of the use of the metal beryllium instead of nickel for the window in the tube and of a rotating magnetic field for controlling the electron stream. The new tube is said to convert quickly the waste products of petroleum stills and coke ovens into rubber, alcohol, acetic acid and valuable drugs and perfumes. It is also stated that moist air is converted directly into nitric acid, that synthetic rubber may be made with astonishing rapidity, and that with cold water and air as raw materials it is possible to make alcohol, methanol, acetic acid, ether and other such products. In fact, the claims that are made for this new agent are so remarkable that, if they are substantiated, it would appear that an entirely new era in synthetic chemistry is opening. It is to be hoped that these claims, which appear at present almost extravagant, will be duly substantiated by repetition and scientific report. Accounts of such further studies will be awaited with the keenest interest.—*Electrical World.*

Electrochemistry and Electrometallurgy

ANNUAL REPORT OF COMMITTEE ON ELECTROCHEMISTRY AND ELECTROMETALLURGY*

To the Board of Directors:

The Committee on Electrochemistry and Electrometallurgy makes its annual report as follows:

The revision of the Institute's standards for storage batteries which was proposed by this committee several years ago has been completed by Working Committee No. 37. The revised standards were adopted by the Board of Directors February 16, 1928 and have been published.

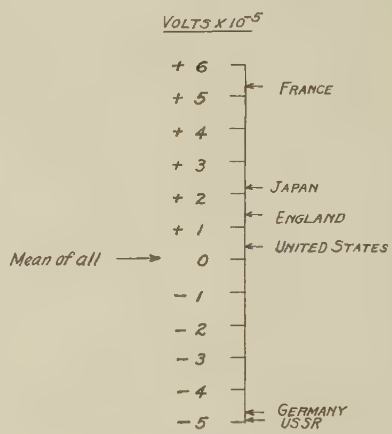
Standards for the international electrical units continue to receive attention at the National Standardizing Laboratories. These standards are the basis for electrical measurements of both the engineer and the physicist. The standards for the international system of units are essentially electrochemical and it is appropriate, therefore, to review briefly the present situation in regard to them. Since 1911 fundamental measurements of current have been based upon wire resistances and the value determined for the Weston normal cell by an international technical committee which did its experimental work in Washington during the year 1910. At that time values to be assigned to the wire resistance coils were agreed upon. No detailed specifications for either the standard cells or the silver voltameter which serves as the international standard for the measurement of current were agreed upon, but the work of preparing such specifications was continued by several of the national laboratories until interrupted by the War and a high degree of uniformity was attained in the voltameter measurements.

The interlaboratory comparisons of standard cells were also interrupted by the War and it is only within recent months that we have obtained comparisons of the value of the volt in the principal countries. Direct exchange of standard cells has been made between the Bureau of Standards and several foreign laboratories. Several groups of cells have been taken also to the various national laboratories by representatives of the Central Chamber of Weights and Measures at Leningrad. A report by M. Malikoff and M. Kolossof has recently communicated the results of their comparisons. On the basis of their report as well as the direct exchange of cells, the accompanying figure has been prepared to show the relation of the volt in six countries at the present time.

The maximum differences are rather larger than was to be expected. This should not be interpreted as meaning that the saturated cell is not reliable or reproducible since the value for the cell is a derived value and may therefore include uncertainties in the value of the ohm or errors in the use of the voltameter, or whatever other means may have been employed for determining the cell values from time to time.

The procedure for maintaining the volt by means of the Weston normal cell at the various laboratories differs very greatly. A redetermination of the international ampere by means of the silver voltameter has been undertaken by the Bureau of Standards. Work of this character has not been done previously for 15 years.

Whatever the outcome of the present discussions as to the advisability of continuing the international system of electrical units or changing to the absolute,



RELATIVE VALUE OF THE VOLT IN SIX COUNTRIES AT THE PRESENT TIME

c. g. s. system may be, the maintenance of the reference standards, particularly the standard cell and the wire standards for resistance will be none the less important. If the absolute units are eventually adopted in place of the present international system, the silver voltameter and the mercury ohm will be discarded.

The fifty-third meeting of the American Electrochemical Society included a symposium on the chemical production of electricity. Eighteen papers were presented on primary cells, storage batteries, rectifiers, and electrolytic condensers. The feasibility of making dry cells without the use of manganese ore was described in several papers. Graphitic oxides have become a commercial possibility as a substitute for manganese dioxide, but no immediate change in the construction of dry cells is likely. The graphitic oxides, however, should find other applications where a convenient source of loosely held oxygen is needed. The absorptive

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*COMMITTEE ON ELECTROCHEMISTRY AND ELECTROMETALLURGY:

G. W. Vinal, Chairman.

Lawrence Addicks,	E. B. Dawson,	J. A. Sede,
A. N. Anderson,	F. A. J. Fitzgerald,	Magnus Unger,
T. C. Atchison,	W. E. Holland,	John B. Whitehead,
Farley G. Clark,	F. A. Lidbury,	J. L. Woodbridge,
Safford K. Colby,	C. G. Schluederberg,	J. L. Yardley.

Presented at the Summer Convention of the A. I. E. E., Denver, Colo., June 25-29, 1928.

properties of finely divided carbon have also made possible the construction of primary cells of large capacity, subject only to the renewal of the zinc and the electrolyte.

The development of satisfactory aluminum electrolytic condensers has been important in the telephone field. These condensers have a service life yet to be determined. Some have been in service more than five years and others, operating under test conditions in the laboratory, have passed eight years. The capacity depends somewhat on the formation and the conditions of service. Condensers for 24-volt circuits have a nominal capacity of 1000 μ f. and weigh about 40 lb.

An electrical distillation method described in a recent paper before the Electrochemical Society has been developed for the manufacture of chemically pure hydrochloric and nitric acid. By this means a continuous process has become possible, utilizing electrical energy in place of fuel, with added advantages of greatly reduced cost and an improved product.

Electric melting of steel and iron has maintained its already established position. Complete data are not available on furnace installations during the past year, but a considerable number of new installations include the 'Lectromelt furnaces. The United States is believed to lead the world in the production and utilization of the electric furnace. One noteworthy installation for which an order has been placed during the early part of 1928 is for a 60-ton steel-melting furnace to have an installed transformer capacity of 20,000 kv-a. The phrase "electric steel" has now become a trade mark of superior quality.

Increasing interest has been noted in the possibility of providing greater uniformity in composition and physical properties of cast iron and this affords a promising field for electric furnaces.

The induction type of furnace, sometimes referred to as the high-frequency furnace, has appeared in the ferrous field for the production of alloy steels. In the past, the opinion has been held that the induction furnace would not be useful in the iron and steel industry although it had found a place for itself in the nonferrous field. At the present time some are inclined to think that the widest application for the induction furnace will eventually be in the iron and steel industry. The design of a one-ton steel melting furnace of the induction type is now in the development stage. During the past year new installations have been devoted largely to the manufacture of high-grade special steels and alloys.

Another development in the electric furnace field has been the introduction from France into this country of the Miguet electric furnaces. Electric furnace engineers have recognized the desirability of using large electrodes in order to produce more efficient operation and better quality of production. The electrode in the Miguet furnace covers the entire molten charge, that is, the diameter of the electrode is equal to the diameter of the bowl.

Electric melting in the brass industry is a development of comparatively recent years but it has now become firmly established by affording a control of the product that was previously lacking and by improving working conditions. The smaller brass foundries have been somewhat slower in adopting electric heat for melting than the larger plants in the wrought brass industry, but relatively small furnaces of the single-phase type are now becoming more common.

Increased interest has been shown in the wide application of electric furnaces to various other industries and of particular note is the recent application of electric furnaces to glass melting. This has been a difficult problem to which extended research has been devoted and it is only recently that practical installations have been made. The glass charge is used as the resistor.

Industrial electric heating and annealing has continued to advance. Recent conferences on this subject have been held at Purdue and Yale Universities. A notable example of electric heating and annealing has recently been carried out at the Bureau of Standards in connection with the cooling of the largest disk of optical glass ever cast in America. Refractories for furnaces used in the glass industry have been improved during the year by the introduction of Corhart cast refractory blocks. These are made by fusing aluminous silicious material in an electric furnace and then casting the material in blocks at a temperature about 1900 deg. cent. This material on cooling has a dense interlocking crystalline structure which is nonporous. Tests which have been made in the glass industry show that it has much longer life than any other refractory previously used in that work.

Among the resistors for furnaces, there has been further development in what is known as the Globar elements. These elements are made of silicon carbide. The idea of using this material as an electrical resistor in high temperature work is not new, but it has not been used extensively until recently. Silicon carbide has a large negative temperature coefficient and when used as a resistor was not entirely stable. That is, its resistance tended to increase after a short period of use. During the past year a much more stable resistor of this type has been made and these are now obtainable in large sizes, some as large as 2½ in. in diameter and 5 ft. long with an electrical rating as high as 25 kw. per bar. Another difficulty with these resistors has been overcome by a method developed within the past year for improving the electrical contact at the terminals.

Chromium plating continues to be the center of interest in the electroplating field. Clearing of the patent situation will doubtless further stimulate the use of this metal in electrodeposition. One of the most interesting developments during the past year has been

in connection with chromium plated tools. The industry has reached a stage where the demand for chromium plated-ware is far in excess of the supply.

Cadmium plating is proving valuable as a preventative of rust and its use is growing on this account.

Many attempts have been made to develop satisfactory methods of electroplating aluminum and its alloys, but few of these hitherto described have been successful. Adherent smooth deposits of nickel and other metals on a roughened aluminum surface have now become possible by methods recently described to the Electrochemical Society. These methods vary in detail and are adapted to pure aluminum as well as to each of a number of its alloys. The plated aluminum has advantages by reason of its improved appearance as well as its resistance to abrasion.

The Copper and Brass Research Association has been instrumental in making the uses for copper and brass better known to the public. Evidence of this is found in the fact that the use of brass pipe has increased over 200 per cent in the last three years. The older copper refineries are said to be planning extensive modernization programs chiefly along the line of reducing the power cost.

The output of electrolytic zinc continues to grow as a result of available cheap zinc concentrates which can be handled by this method. This affords a valuable outlet for electrical energy which is likely to increase. The output of electrolytic zinc from aqueous sulphate solution is estimated at the present at 500 tons a day as compared with 100 tons at the close of the War. An increased capacity for the production of electrolytic zinc is forecast for the coming year as several large electrolytic plants have recently been built or projected and some chemical engineers say the time is not far distant when virtually all zinc will be electrolytically refined, as in the case of copper, because of the better quality of the product. The development of the de Laval electrothermic process in Sweden by American interests may, however, have an important result in this field.

In the lead field, additional Betts plant capacity is being built and it seems possible that the demand for lead which is very low in bismuth may become more general. At Kellogg, Idaho, and in Peru, the Tainton process of recovering lead electrolytically from leach liquors along lines analogous to the zinc work is in development.

In the field of aluminum and its alloys a new form of sheet material combining the strength of the alloy and the resistance to corrosion of pure aluminum has recently appeared under the name, Alclad. This consists of a heat treated aluminum alloy base with a smooth nonporous surface of pure aluminum alloyed to the core. This material is expected to overcome serious difficulties which have been experienced with aluminum alloys in the past. Magnesium is finding increasing use in the aluminum alloys of high strength. Uses for the very pure aluminum prepared by the Hoopes process are increasing.

The chief interest in the production of metals from fused electrolytes has recently centered around the large aluminum plant now being constructed at Arvida, Canada. The capacity of this plant is planned to equal the present world production of aluminum. Two sections of the plant have been put in operation. The construction of all-metal airplanes is expected to be an important factor in providing an outlet for the greatly increased production of the light metals.

Beryllium has risen to a position of importance among the metals produced from fused electrolytes. Three per cent of Beryllium added to iron produces a steel and an equal quantity added to copper makes a valuable bronze. Rare metals are being produced on a limited scale by the electrolysis of fused salts and of these the most notable is probably Zirconium.

The use of electrolytic hydrogen in the production of synthetic ammonia has been increasing. Several large installations are planned for this year in Japan and Norway. One of the objections in the past to the electrolytic manufacturing of oxygen has been the lack of a market for the byproduct, hydrogen. The use of atomic hydrogen in welding operations promises a possible balance to make possible the economic production of electrolytic oxygen and hydrogen in place of liquification equipment now used for making oxygen alone.

A new type of oxy-hydrogen cell has recently been designed to operate at high temperatures without undue deterioration. The larger cells are rated for 2.3 volts at a maximum current of 15,000 amperes. These cells are said to be able to follow the normal load in somewhat the same way as the storage battery when charging at a variable rate and to do this without any great change in efficiency. Off-peak energy converted to direct current can be absorbed with a consequent improvement in load factor and it is claimed that the cells may be operated on 3300-volt circuits. It is suggested that under some conditions the large scale production of these gases at a low cost might reach a point where they could be used in the production of gas for heating purposes.

The materials for nitrogen fixation are so universally available that the problem of nitrogen fixation and the use of the products for fertilizer, munitions, or otherwise is largely a problem of national requirements, as to which each nation can reasonably hope to be independent. The development of nitrogen fixation, however, depends on the economic conditions and is in the line of decreasing cost of production wherever possible. Electric power is not available cheaply enough to make the arc process a likely competitor of the other processes. The synthesis of ammonia is developing most rapidly at present.

The great development in small rectifiers of the electrolytic type which was noted several years ago in the radio field has been checked by the recent

development of a-c. radio sets and the so-called dry or electronic rectifiers. Valuable information as to the details of improvements made in the aluminum rectifier as well as other types have become available. Mechanical rectifiers for high-voltage alternating current have been displaced by the vacuum tube.

In the field of electrochemistry of gases, outstanding developments are largely the researches of Dr. Lind and his associates who have been able to produce reactions at low temperatures without use of high voltages by exposing the gases to the emanations from radium. Similar work has been done by Daniels and others on the synthesis of ozone and nitric oxide by the use of high-voltage cathode rays. The use of ozone for the purification of drinking water has trebled within the past few years.

Outlets for electrical energy in various industries that have not previously made extended use of electricity are significant. In the paint, varnish, and lacquer industries the electrolytic production of lead carbonate is increasing. The synthetic preparation of acetic acid, acetone, and methyl alcohol in which electrolysis may play a part, has had an important effect in replacing products formerly obtained by wood distillation.

The heavy clay industry has made progress in the use of electrical machinery but is still behind in the development of such lines. Brick manufacturers are beginning to realize the advantages of electricity as a means of saving labor and the proper control of the products.

On all sides we find a constantly increasing demand for new products to meet conditions which were unknown in the past. Everywhere there is an increasing interest in the work of the research laboratories and the demand for greater results from research people.

The committee wishes to acknowledge valuable suggestions for the preparation of this report which have been made by Prof. C. G. Fink, secretary of the American Electrochemical Society.

George W. Vinal, *Chairman.*

Abridgment of

Calculation of the Capacitance Between Two Wires of a Three-Conductor Cable

By Y. W. Lee[1]

Enrolled Student

Synopsis.—*This paper develops a formula for calculating the capacitance between two wires of a three-conductor cable. A direct method of calculation is employed, based on the work of Doctor H. B. Dwight. This method gives accurate results independent of empirical or restricted premises.*

In the electrical problems of underground cables, a factor which is very difficult to determine is the "geometric factor," which, as the name implies, involves the dimensions of the cable. The geometric factor is very closely related to the capacitance of the cable; and as a matter of fact, it is a constant times the reciprocal of the capacitance.

In a three-conductor cable there are nine geometric factors, and of course as many capacitances resulting from the different connections of the four elements of the cable; namely, the three conductors and the sheath. The capacitance of the three wires against the sheath, and the capacitance between two wires are the most important ones, as the other seven are expressible in terms of them.

In the determination of the geometric factor in problems such as the calculations of the dielectric loss, the stress under three-phase voltage, the insulation resistance, the charging current, and so on greater accuracy is demanded.

The inverse method of determining the capacitance by first assuming the distribution of the charges, then calculating the equipotential lines, is good only in a few cases where these lines agree with the shapes of the conductors. This method is not applicable to the three-conductor cable. An attempt has been made to graphically correct the lines of flow to secure a more accurate result; but this has not been extended to the case to be considered in this paper. All published formulas relating to the capacitance in a three-conductor cable, with the exception of Doctor H. B. Dwight's, are either empirical or restricted.

Doctor Dwight of the Massachusetts Institute of Technology presented in the Transactions of the A. I. E. E. of 1924, a direct method for calculating the capacitance of conductors. The most important case he worked out was the capacitance of the three wires against the sheath in a three-conductor cable. The capacitance between two wires of the cable remained to be determined in order to complete the accurate determination of the geometric factors.

With the valuable assistance of Doctor Dwight, the author has derived a formula for the capacitance between two wires in a three-conductor cable. A check has been made against the experimental curves published by Mr. D. M. Simons. The difference is small, being 3.4 per cent. This calculation was done as thesis work in the Electrical Engineering Department of the Massachusetts Institute of Technology.

The complete paper will be published in the Transactions. It will contain the outline of the method of calculation, the statement of the formula, and the result of a check against an experimental value.

1. *Graduate Student of the Mass. Institute of Technology, Boston, Mass. Complete copies of paper upon request.*

Under the provisions of an Act of Congress, approved May 26, 1928, the Secretary of War is authorized to transfer or loan aeronautical equipment to museums and educational institutions. Information relative to taking advantage of these loans may be secured from the Secretary of War.

Atlanta Regional Meeting October 29-31

A most interesting program particularly attractive to members in the South has been arranged for the Regional Meeting which will be held October 29-31 in Atlanta, Ga., with headquarters at the Atlanta-Biltmore Hotel.

Four technical sessions are scheduled under the general headings of power development, power operations, communication and high voltage, and textile. The titles of the papers are given in the accompanying program.

There will be a general session, also, with addresses by some well-known speakers.

A feature of the meeting will be the Student Session at which questions of student activities will be discussed, and several student papers presented.

Inspection trips to points of engineering interest and other entertainment features have been planned including a dinner-dance on the evening of Tuesday, October 30.

Those who expect to attend the meeting are requested to notify O. O. Rae, the chairman of the Registration Committee, as soon as possible, addressing him in care of the Westinghouse Elec. & Mfg. Company, 426 Marietta Street, Atlanta, Ga.

Requests for hotel reservations should be forwarded directly to the hotel desired. Following below are listed room rates at the Atlanta-Biltmore, the headquarters hotel, and other hotels in the vicinity.

HOTEL ROOM RATES

Hotel	Daily Room Rates with Bath Single	Double
Biltmore	$4.00 and up	$5.00 and up
Henry Grady	2.50	4.50
Robert Fulton	2.50	4.00
Cecil	1.50	3.00
Piedmont	2.00	3.50
Ansley	3.00	5.00
Winecoff	2.50	4.00

The following general committee has charge of arrangements for the meeting: C. O. Bickelhaupt, Vice-president in Southern District, Chairman; T. H. Landgraf, Vice-chairman; C. E. Bennett, G. N. Brown, H. A. Coles, W. R. Collier, F. M. Craft, C. L. Emerson, T. W. Fitzgerald, E. H. Ginn, E. S. Hannaford, W. E. Mitchell, O. O. Rae, G. J. Yundt.

PROGRAM FOR ATLANTA REGIONAL MEETING OCTOBER 29-31

9:00 A. M. MONDAY, OCTOBER 29

STUDENT ACTIVITIES SESSION, Prof. E. S. Hannaford, Presiding:

Address of Welcome, C. O. Bickelhaupt, Vice-President, A. I. E. E. in Southern District

Student Activities, H. H. Henline, Assistant National Secretary, A. I. E. E.

Five Papers on Student Activities, by students

General Discussion

2:00 P. M. MONDAY, OCTOBER 29

POWER DEVELOPMENTS SESSION

Economies in Central Power Service, W. S. Lee, Consulting Engineer, and Vice-President, Duke Power Company

Southeastern Power and Light Company's System, A. T. Hutchins, Southeastern Power and Light Company

Translations between Sound and Light, J. B. Taylor, General Electric Company

8:00 P. M. MONDAY, OCTOBER 29

GENERAL SESSION (Public invited)

Presentation of cup for Best Student Paper, H. H. Henline, Assistant National Secretary, A. I. E. E.

Introductory Remarks, P. S. Arkright, President, Southeastern Power and Light Company

The Existing Radio Problem, Judge E. O. Sykes

Science and Research in Telephone Development, S. P. Grace, Bell Telephone Laboratories, Inc.

9:00 A. M. TUESDAY, OCTOBER 30

COMMUNICATION AND HIGH-VOLTAGE SESSION

Carrier-Current and Supervisory Control on Alabama Power Company's System, E. W. Robinson and W. I. Woodcock, Alabama Power Co.

Line Characteristics for Carrier Communication, C. A. Boddie and R. C. Curtis, Westinghouse Elec. & Mfg. Co.

Impulse Flashover of Insulators, J. J. Torok and W. Ramberg, Westinghouse Elec. & Mfg. Co.

A Study of High-voltage Flashovers, J. T. Lusignan, Jr., General Electric Co.

TUESDAY AFTERNOON, OCTOBER 30

Inspection Trips

7:00 p. m. Tuesday, October 30

Dinner-dance at Atlanta-Biltmore Hotel

9:00 A. M. WEDNESDAY, OCTOBER 31

TEXTILE SESSION

Electric Drive for Variable-Speed Spinning, E. A. Untersee, General Electric Co.

Motor Drives for Cards and Roving Frames, H. W. Reding, Westinghouse Elec. & Mfg. Co.

Electrification of the Textile Industry in the Southeast, A. G. Stanford, Central Georgia Power Co. and E. M. Clapp, Robert & Co., Inc.

2:00 P. M. WEDNESDAY, OCTOBER 31

POWER OPERATIONS SESSION

Power-Limit Tests on Southeastern Power and Light Company's System, S. M. Jones, Alabama Power Co. and Robert Treat, General Electric Co.

Application of Auto-oscillograph Equipment for Power Systems, A. Dovjikov, Westinghouse Elec. & Mfg. Co.

Photo-Electric and Glow-discharge Devices, J. V. Breisky, and E. O. Erickson, Westinghouse Elec. & Mfg. Co.

Short-circuit Testing on Alabama Power Company's System, H. J. Scholz, Southeastern Engg. Co. and C. B. Hawkins, Alabama Power Co.

The American Welding Society's Program

At the coming Fall Meeting of the American Welding Society, October 8-12 inclusive, Bellevue Stratford Hotel, Philadelphia, Pa., there will be presented much information of high technical value and also a generous program of social entertainment for those who attend. As admission to the Commercial Museum and some other social events will be by badge only, all members and guests are requested to register early with Mr. M. M. Kelly, Secretary.

The technical sessions will start the morning of Tuesday, Oct. 9, and will include the subjects of *Welding in Heating, Ventilating and Plumbing Industries*, by R. A. Jock, Domestic Engineering, the *Testing of Joints for Aircraft Structures Prepared Under Procedure Specifications*, presented by H. L. Whittemore, Bureau of Standards, and H. H. Moss of the Linde Air Products Company; *Welds at Elevated Temperatures*,

by Professor C. Moser, of Stanford University, *Formula for Computing Design Stresses for Pressure Vessels*, by S. W. Miller of the Union Carbide and Carbon Research Laboratories. They will continue Wednesday with papers on *Running a Successful Job Welding Plant*, by J. S. Oechsle, president of the Metalweld, Inc., *Welding in the Automobile Industry*, by J. W. Meadowcroft, Asst. Works Manager of the Edward G. Budd Mfg. Co.; Thursday, *Design of Welded Structures*, by F. P. McKibben, Consulting Engineer of the General Electric Co., *Erecting a Building by Welding*, by J. F. Lincoln, of the Lincoln Electric Co., *Oxy-Acetylene Cutting in the Structural Field*, by H. E. Rockefeller of the Linde Air Products Co.; Friday, Special Films on *Studies of the Metal Arc* by Doctor Karl Bung, German Engineer, and the *Design of Machinery Parts by Use of Welding of Steel Shapes*, by Messrs. Hague, Marthens, and Brinton of the Westinghouse Electric & Mfg. Co. There will also be an evening session on Structural Steel Welding. Entertainment for the ladies will include a luncheon in the Betsy Ross Room of the Benjamin Franklin Hotel, a bridge party, and an automobile tour of Valley Forge. The Grand Ball will also be held at the Benjamin Franklin Hotel.

Convention of the American Gas Association

The Tenth Annual Convention of the American Gas Association will be held at Atlantic City on the Young's Million Dollar Pier October 8 to 12.

AMERICAN ENGINEERING COUNCIL

MEETING OF THE ADMINISTRATIVE BOARD

The next meeting of the Administrative Board of the American Engineering Council will be held in Pittsburgh, October 19 and 20, under the auspices of the Engineers' Society of Western Pennsylvania. President Arthur W. Berresford of New York will preside.

Meeting of the American Military Engineers

An invitation is extended to Institute members to attend a meeting of the New York Chapter of the Society of American Military Engineers which is to be held in the auditorium of the Engineering Societies Building November 12, 1928 at 8 p. m. Charles E. Dawes, Vice-president of the United States, will be the speaker.

National Exposition of Power & Mechanical Engineering

One of the greatest annual events of industry and engineering practise which is awaited anxiously by manufacturers of industrial equipment and kindred products is the Seventh National Exposition of Power & Mechanical Engineering at the Grand Central Palace, New York, December 3-8, 1928.

The Power Exhibits will include instruments of precision, electrical equipment, pipe and piping, valves and fittings, steam specialties, pumps, engines and turbines, coal companies, pulverized coal equipment, oil burning equipment, stokers and grates, boiler makers, feed water heaters, feed water softeners, etc., fire brick, arches, etc.; for heating and ventilating, radiators, cooling towers, blowers, air conditioners, air filters, gaskets and packing, separators, furnaces, boilers, and grates and stokers; for tools, tools and machine tools, lubricants, and lubricators, and for transmission equipment, belting, belt dressing, belt fasteners, belt chains, pulleys, drives, transmissions, clutches, bearings, gears, couplings, and speed reducers.

There will be a miscellaneous group, also, including 14 exhibits of safety appliances, numerous exhibits of material handling equipment, insurance firms which specialize in boiler and plant insurance and many other interesting exhibits.

The power show will offer a new opportunity this year, in the Marine Field, in a new avenue for better equipment in construction and operation.

The American Society of Mechanical Engineers, the American Society of Refrigerating Engineers, and the American Institute of Chemical Engineers all convene during the Exposition week and visit the Show.

The Pacific Coast Convention

A SUCCESSFUL AND ENJOYABLE MEETING AT SPOKANE, WASH.

The Seventeenth Annual Pacific Coast Convention held at the Davenport Hotel, Spokane, Washington, August 28-31, 1928, was considered very successful and enjoyable by the 250 members and guests present. The technical program was excellent in quality and variety of papers, and the entertainment features were very attractive. At five technical sessions, 19 papers were presented and a very interesting illustrated address on *Lichtenberg Figures* was given on Wednesday evening by Dean C. E. Magnusson of the University of Washington.

STUDENT ACTIVITIES

At two technical sessions held on Tuesday and Thursday mornings, nine papers by engineering Students in the Pacific and North West Districts were presented. In addition to these sessions, a Joint Conference on Student Activities of the Pacific and North West Districts was held, and there was a luncheon for the Counselors, Branch Chairmen, and Institute officers. Reports upon all the Student sessions are given in the Student Activities Department.

ENTERTAINMENT

The reception and informal dance held on Tuesday evening opened the social program of the convention, and those present spent a very enjoyable evening.

At the banquet held on Thursday evening, Vice-President G. E. Quinan of the North West District acted as toastmaster, and brief talks were given by President R. F. Schuchardt, and Vice-President E. R. Northmore of the Pacific District. Several entertainment features were provided by J. S. Thompson, President of the Pacific Electric Mfg. Co., and four other Institute members. The First Paper Prize and the Best Paper Prize for the North West District for 1927 were presented by H. H. Schoolfield, vice-president, North West District 1926-1928, to Ray Rader, Office Engineer, Puget Sound Power and Light Co., who received both awards for his paper entitled *A Discussion of Short-Circuit Problems and the Application of the Testing Board in their Solution*. This paper was presented at a meeting of the Seattle Section on May 17, 1927. Each prize consisted of a certificate signed by the District officers and a check for $25.00. Prizes for the golf tournament held on Wednesday afternoon were presented as follows:

Low net, John B. Fisken cup and a golf bag, George D. Luther. Low net, runner-up, wood club, J. R. Murphy. Low gross, brief case, Geo. D. Luther. Low gross, runner-up, set of metal cups, H. R. Pirrett. Five blind holes, golf club, H. R. Pirrett. Five blind holes, runner-up, tie between Geo. D. Luther and R. J. Cobban, decided by putting contest in dining room, and won by Geo. D. Luther who received a seal leather pocket book. High gross, six golf balls, Professor R. W. Sorensen. Birdies, one golf ball for each, John B. Fisken 2, Geo. D. Luther 1, J. R. Murphy 1, G. E. Quinan 1, Berkeley Snow 1. Ladies' prizes for putting contest and bridge were presented as follows: Putting contest, first prize, silver ice bucket, Mrs. Bernhard Olsen; second prize, dish, Mrs. Carolyn Fisken Kapek; bridge, first prize, clock, Mrs. Lora C. Larsen; second prize, silver water

pitcher, Mrs. Dorothy Hunt; booby prize, perfume, Mrs. R. D. Sloan.

On Friday evening, H. T. Plumb, Engineer, General Electric Company, Salt Lake City, gave an interesting description and demonstration of the action of a photoelectric cell, and the following motion pictures were shown: *Voices Across the Sea, What the Job Pays*, and *The Girl Who Found Herself*.

Other events for the ladies were, a drive to the Manito Golf Club for bridge luncheon; sight-seeing trip of city followed by tea and music at the Spokane Country Club; and auto-bus trip to Hayden Lake and Tavern luncheon.

Several very attractive inspection trips available for Saturday and Sunday were; Chelan hydroelectric station of the Washington Water Power Company; outdoor hydroelectric station of the Pacific Power and Light Company at Lewiston, Idaho; Long Lake hydroelectric station of the Washington Water Power Co., and the Coeur d'Alene mining district, and the electrolytic zinc plant of the Bunker Hill and Sullivan Mining and Concentrating Company at Kellogg, Idaho.

At a luncheon conference on Thursday, at which Vice Presidents Northmore and Quinan, J. Hellenthal, Secretary of North West District, representatives of all Sections within the Pacific and North West Districts, and chairman of the Vancouver Section were present, it was decided to recommend that next year's Pacific Coast Convention be held at Los Angeles at a date to be determined later.

At the final technical session on Friday afternoon, resolutions were adopted expressing appreciation of the activities of the Convention Committee, Spokane Section, Davenport Hotel, and other organizations which assisted in making the Convention very successful.

DIGEST OF TECHNICAL DISCUSSIONS

A summary of the discussions at the technical sessions is given in the following paragraphs:

AFTERNOON SESSION, AUGUST 28

Sphere-Gap and Points-Gap Arc-Over Voltage, J. S. Carroll and B. Cozzens.

High-Voltage Gaseous-Conductor Lamps, F. O. McMillan and E. C. Starr.

The Automatic Substation and its Relation to the Electric Distribution System, S. J. Lisberger.

The Design of Power Systems for Stability, R. H. Park and E. H. Bancker.

In the discussion of the Carroll and Cozzens paper it was brought out by E. C. Starr, H. V. Carpenter and others that some of the erratic effects might have been due to the proximity of other objects near the electrodes. Dean Carpenter also suggested that possibly air currents or local concentration of ions in the air might have affected the results. R. W. Sorensen stated that he had used blunt needle points for measuring voltages up to 1,000,000 volts and obtained results with a fair degree of accuracy, perhaps 5 or 10 per cent. Professor Carroll in answering the discussors agreed that great care must be taken in regard to clearances in order that the results may be dependable. In answer to a question he stated that one-meter spheres can be depended upon for accurate measurements for three or four hours after they have been given fifty flash-overs. The number of shots necessary to put the spheres in condition he states is uncertain and depends upon the length of time during which they have been idle and other factors, some of which are unknown. In answer to another question he stated that the corona-current measurements given in the paper were made with two points at high voltage and not from a point to the ground. He thought that in the latter case the form of the current wave would be slightly different. He referred to the fact that the average values in his paper are less than the theoretical values of F. W. Peek and stated that this tends to show that there might be some variation in the sphere gaps. He pointed out that all of his maximum values follow along Peek's curves.

In commenting on the paper by Messrs. McMillan and Starr, E. A. Loew asked if there is a proper voltage for every length of neon tube. He pointed out that in a power arc the maximum power factor which can be obtained is about 70 per cent and asked if it would be possible to operate the tubes at about the same power factor and thus obtain maximum efficiency. C. P. Osborne pointed out the low power factor of these tubes, about 30 or 40 per cent, and stated that he thought that the sign companies should furnish condensers with the lamps to raise the power factor. D. I. Cone drew attention to the harmonics produced by these lamps and to the possible interference with communication which might be caused by them. J. S. Carroll suggested that three windings might be used on the transformer for connection to a condenser to increase power factor. This arrangement he thought would be economical. In answering Professor Loew's question, Mr. McMillan stated that a power factor as high as 70 per cent is not possible because the starting voltage must be considerably higher than the operating voltage of the lamp. The maximum power factor obtainable in practise he stated is about 50 per cent. Furthermore, he explained that from a commercial standpoint it is not desirable to make a large number of sizes of lamps.

M. T. Crawford in a written discussion on Mr. Lisberger's paper pointed out that the problem in the rural districts is quite different from that in the cities in connection with automatic distribution. He stated that for rural service his company has installed a number of pole-type transforming stations up to 600 kw. in size for stepping down from 13,000 to 2000 or 4000 volts for distribution purposes. A number of these pole-type stations have been equipped for automatic switching on both primary and secondary sides. The total cost for such a substation of 600-kw. capacity with three regulated lighting feeders and one unregulated power feeder is about $12,000. C. E. Carey commented on Mr. Lisberger's mention of the use of boiler-plate tanks for induction regulators. He stated that the corrugated thin-metal tank has been proved by test to withstand explosions much more satisfactorily. L. R. Gamble stated that analyses made in Spokane would indicate that the annual charges for an a-c. network ran from 50 to 70 per cent lower than those for a d-c. network. J. Hellenthal stated that in Seattle automatic substations have been found very economical from the standpoints of design and of operation. He stated that in stations with capacities from 6000 kv-a. to 9000 kv-a. costs on the order of $19.00 to $17.00 per kv-a. can be obtained. A. P. Sessions stated it is desirable to know when a switch in an automatic station has tripped and locked out and that his company employs a telegraph-type relay connected to telephone lines running from the stations to the switching center.

In discussing the paper by Park and Bancker, L. F. Hunt enumerated five ways of improving stability namely, (1) preventing flash-overs, (2) clearing faults rapidly, (3) adding parallel transmission lines, (4) preventing over-speeding of generators, and (5) providing quick excitation of generators.

MORNING SESSION, AUGUST 29

The Electrolytic Zinc Plant of the Sullivan Mining Company, E. R. Fosdick.

Great Northern Railway Electrification in the Cascades, E. L. Moreland and R. D. Booth.

Power Supply for Railway Signals and Automatic Train Control, C. F. King.

Automatic Mercury-Arc Power Rectifier Substation, L. J. Turley.

In commenting on Mr. Turley's paper, C. E. Baker warned that a direct comparison between the power factors of a rectifier and of rotating apparatus may be misleading on account of the distortion of the current drawn by the rectifier. D. W. Proebstel stated that rectifiers did not always cost more than synchronous

condensers and that this depends upon the voltage. For instance, he stated there are two rectifiers in Portland with a rating of 750 kw. each whose costs are probably lower than that of synchronous converters of the same rating. G. E. Nott stated that in Los Angeles the use of resonant shunts for reducing telephone interference caused by rectifiers have proved quite satisfactory. The addition of shunts he stated reduced the interference to approximately 13 per cent of the value which obtained without shunts, and to 60 per cent of that produced by existing rotating equipment which however was of older design and caused more interference than similar equipment of recent manufacture.

Afternoon Session, August 30

Movements of Overhead Line Conductors During Short Circuits, W. S. Peterson and H. J. McCracken.

Economy in the Choice of Line Voltages and Conductor Sizes for Transmission Lines, E. A. Loew.

Generalization of Transmission-Line Diagrams, H. V. Carpenter.

Residual Voltages and Currents in Power Systems, L. J. Corbett.

E. F. Pearson in commenting on the first paper of this session suggested the use of current-limiting reactors or high-reactance transformers for preventing the swinging of conductors. He suggested for long spans already installed the use of a semi-rigid string of small strain insulators at the center of the spans. A. C. Pratt stated that on heavy 2300-volt distribution circuits his company has successfully used spreaders which consist of ordinary cross arms and pin-type insulators, these being located at the center of long spans. L. F. Hunt stated that one way in which his company has reduced the swing of conductors is by very rapid relaying. L. J. Corbett stated that he did not believe trouble is to be feared from three-phase short circuits and that the maximum condition of trouble will occur on a single-phase short circuit between two conductors.

In discussing the paper by E. A. Loew, L. R. Gamble stated that his company had been investigating a line 130 mi. in length and he had checked his calculations with the curves in the paper with very close agreement. J. F. H. Douglas pointed out the fact that for lines less than fifty miles in length it will frequently be found that an operating voltage less than 80 per cent of the critical corona voltage will be most economical. He explained another method of arriving at the most economical voltage which takes into account the common voltages used in practise on transmission lines. He pointed out also that the cost of insulators should be considered and that this will sometimes determine a lower voltage as desirable. In a written discussion V. B. Wilfley pointed out another factor which should be considered in designing a line, namely, the maintenance of stability, because after certain limitations are reached this may be the limiting factor. J. S. Carroll pointed out that with new cable the corona losses are higher than they are after the cable has been in service for some time. He stated that for reduction of corona the copper conductor with a bronze center looks promising. He advocated the entire elimination of corona.

In commenting on the paper by H. V. Carpenter, D. I. Cone warned that in making small-model tests, particularly with condensers and coils, some of the quantities which may be assumed as constants are not constant, but are functions of the frequency.

A. W. Copley commenting upon Mr. Corbett's paper warned that the solution offered for inductive-interference troubles from triple harmonics is not a general solution, but can be used successfully in specific cases. D. I. Cone and others brought out the importance of the factor of saturation of the transformer iron, declaring that when the iron is saturated a very small voltage change will cause a large change in the exciting current harmonics. R. A. Kistler stated that in some cases residual current or its prominent harmonics have been limited by installation of reactors and resonant shunts in the generator neutral. He suggested in place of inserting resistance in the delta of the star-delta bank, to limit residual current, a resistor might be placed in the neutral of the star side. He thought that this practise might be preferable as it would also tend to limit short circuit currents. Roy Wilkins brought out the fact that whenever a star-delta bank with the star grounded is used on a grounded system, the delta winding must be sufficiently large so that when one phase of the line is grounded the delta will pass enough current to operate the relays on the high-tension side. One apparent method of correcting this trouble he stated is to open the delta, but this has been found unsatisfactory.

Morning Session, August 31

Power-Line Carrier Telephony, L. F. Fuller, and W. A. Tolson.

Problems in Power-Line Carrier Telephony, W. V. Wolfe and J. D. Sarros.

Carrier-Telephony System for Short Toll Circuits, H. S. Black, M. L. Almquist and L. M. Ilgenfritz.

L. M. Ilgenfritz in comparing power-line practise with ordinary telephone practise pointed out that the carrier schemes used on the Bell System transmit in opposite directions on different frequency bands. J. P. Jollyman in a written discussion stated that the system described by the authors of this paper has been in regular operation for several months and has been very satisfactory. It is not interrupted by power-line switching or even power-line trouble. In a written discussion C. A. Boddie pointed out that it is now recognized that the power line is not a simple circuit for supplying communication and that the standards of communication required by a power company are very rigid. It was his opinion that corona is not responsible for the difficulties encountered in communication over these lines. It was found that noise was caused by discharges which pass between corona shields and the hardware which support them. This source of noise can be avoided by making a firm electrical connection between the shield and the support. He disagreed with the statement that the condenser coupling is superior in efficiency to the antenna coupling and claimed that the type of coupling should be selected according to mechanical rather than electrical considerations. L. F. Fuller declared that he believed that the reduction of the noise on the Pacific Gas & Electric system was effected very largely by the use of coupling capacitors instead of coupling wires. He pointed out that the full advantage of the large number of channels permitted on single sideband transmission cannot be realized until the line itself can be very materially improved. In answering a question J. D. Sarros stated that although no definite proof of the presence of modulation was found, if modulation is present, a single sideband system offers advantages in the reduction of noise.

Afternoon Session, August 31

Lightning Arrester Problems, A. L. Atherton.

High-Voltage Phenomena in Thunderstorms, M. A. Lissman,

Heat Flow from Underground Electric Power Cables, N. P. Bailey.

Cable-Sheath Corrosion in Creosoted Wood Duct, B. A. Freed and R. M. Burns.

R. W. Sorensen stated his agreement with Mr. Atherton that switching disturbances are not serious sources of trouble and also claimed that the quicker a circuit can be interrupted the less the disturbance will be.

A written discussion from H. J. Ryan was read, in which he explained some of the terms and work included in the paper by M. A. Lissman.

In discussing Mr. Bailey's paper, R. H. Park pointed out that Mr. Bailey's calculations were made only for the steady state and he showed how the heat flow would be quite different from cables which are undergoing a load cycle. E. R. Northmore drew attention to the fact that some cables on his company's property which are located in loosely packed sand cannot carry loads which cables in other locations will carry.

D. W. Proebstel in connection with the paper by Freed and Burns stated that he had seen cases of corrosion of cable sheaths which occurred in ducts which were not creosoted. Mr. Freed agreed that the untreated portion of the duct will cause corrosion and stated that there are three courses open to elimination of corrosion; (1) a change in the wood, (2) a better impregnating process, and (3) mixing a compound with the creosote which will neutralize the acid.

CONVENTION COMMITTEE

John B. Fisken, Chairman; M. W. Birkett; Daniel L. Brundige; H. P. Charlesworth; G. S. Covey; James B. Fisken; L. R. Gamble; E. R. Hannibal; D. F. Henderson; D. L. Huntington; W. S. McCrea, Jr.; Richard McKay; E. R. Northmore; Bernhard Olsen; George E. Quinan; J. E. E. Royer; L. C. Williams; Joseph Wimmer; W. L. Winter; J. E. Yates; A. C. R. Yuill. Mrs. L. R. Gamble was Chairman of the Ladies Entertainment Committee.

International Electrotechnical Commission Reports of Bellagio Meeting September 1927

Two volumes containing the papers and reports presented at the Bellagio meeting of the International Electrotechnical Commission have been presented to the A. I. E. E. by the United States National Committee of the I. E. C. These reports cover the subjects of

Volume I.	Rating of Electrical Machinery
	Symbols
	Prime Movers (Steam and Hydraulic)
	Lamp Holders and Bases
Volume II.	Standard Voltages
	Traction Motors
	Insulating Oils
	Rules and Regulations for Overhead Transmission Lines
	Radio Communication
	Measuring Instruments
	Rating of Rivers
	Terminal Markings

and are available to any member of the A. I. E. E. who desires to refer to them. Copies have been placed also at the disposal of the American Society of Mechanical Engineers, American Society for Testing Materials, National Electric Light Association, National Electrical Manufacturers Association, Engineering Societies Library, American Engineering Standards Committee, Department of Commerce, and the office of the Secretary of the U. S. National Committee, Room 1018, 33 West 39th Street, New York, N. Y.

Louvain's Appreciation

Expressing appreciation to all those who participated in raising the fund for the war memorial to American engineers the following letter has been received by Alfred D. Flinn, Secretary of Engineering Foundation from the Secretary of the University of Louvain:

Middelkerke, Belgium
September 1, 1928

My dear Mr. Flinn,

We are still full of the memories of that splendid 4th July day when we came into such delightful contact with our American friends and more specially with the representation of the Engineering Societies of the United States. It was for all the members of the University a great joy to see those American friends who have given to us such a splendid memorial in honor of the brave men who fell in the Great War.

The ringing of the bells has absolutely transformed Louvain. From a city which seemed dead and dull since 1914, when the carillon tumbled down under German fire, it has now become a town full of memories, and the carillon has become a sort of pilgrimage place, where every day since your departure lots of people come to see the American memorial and look at the stars of the clock, representing the American states who contributed to the erection of that splendid gift.

There has not been a day during which no motor cars have carried people from all sides of Belgium who come to visit the tower and the bells, and many Americans have already passed by, proud of their country and filled with friendly feelings toward those who have to watch over the memorial of the fallen engineers.

There has been a moment when every man of Louvain has had tears of emotion in his eyes. That was on 4th August last, at 9:30 in the morning, when as every year since the end of the war, all the bells of Louvain were ringing in memory of the violation of Belgium soil by the German Army. When suddenly, the "Liberty Bell" began to strike, overpowering all the other bells of the city, many persons ran to the Place du Peuple and stood there, looking at the tower, deeply moved, as if the voice of the dead American engineers was spreading through the air and saying: "This is the Liberty Bell, now ringing in free Belgium on this fateful 4th of August. Remember that we died so that you might live and be free."

I, personally, staying in the garden of my home, have listened, with my family, to the voice of the Liberty Bell, and, deeply impressed, have prayed for the dead engineers.

We have already had many concerts on the carillon, which has now become in the everyday life of the people of Louvain what I would call a part of their soul. It would be henceforth unthinkable to have Louvain without that carillon, and when one is walking through the fields far out from the city, everywhere he sees that tower and carillon, and the aspect of Louvain with the Engineers' Memorial is now something of a perpetual remembrance of these great things which you intended the memorial should keep alive in our memory.

Monsignor Ladeuze* is specially proud of "his" carillon. I have surprised him more than once, towards the evening, in his garden, listening to the bells.

I hope you kept all the good impression of your stay amidst your Belgian friends and I am sure that the ties of friendship bound during that 4th July day will endure for ever.

Please, give my best and friendliest regards to all those of the Engineering Societies whom I had the pleasure to meet, and believe me

Affectionately yours,
L. Van der Essen.

*Rector of the University of Louvain.—Editor.

A. I. E. E. Section Activities

Future Section Meetings

Pittsburgh

Railroad Electrification, by F. H. Shepard, Westinghouse Electric & Mfg. Co. October 16.

Transient Phenomena, by K. B. McEachron, General Electric Co. November 13.

PAST SECTION MEETINGS

Denver

Picnic Meeting. August 10. Attendance 90.

Louisville

Modern Transportation, by C. H. Blackman, Louisville & Nashville Railroad Co. Motion picture, entitled "An Electrified Travelogue," was shown. June 12. Attendance 12.

Mexico

Dinner Meeting. Nomination of officers. August 7. Attendance 31.

Funcionamiento de la Red Automatica de Baja Tension, by E. Leonarz, Jr., Mexican Light and Power Co. The following officers were elected: President, P. M. McCullough; Secretary, F. Aubert; Treasurer, E. F. Lopez. September 4. Attendance 44.

Nebraska

Business Meeting. The following officers were elected: Chairman, C. D. Robison; Vice-Chairman, V. L. Hollister; Secretary-Treasurer, C. L. Skarolid. July 2. Attendance 36.

Niagara Frontier

Electrification of the Cement Industry, by A. J. Zook, Chief Engr., Great Lakes Portland Cement Co., and

Report of Regional Meeting of A. I. E. E. at New Haven, Conn., May 9-11, 1928, by L. E. Imlay, Chairman. A dinner preceded the meeting. May 18. Attendance 90.

Welding of Steel Structures, by F. P. McKibben, Consulting Engr., General Electric Co. May 25. Attendance 67.

Philadelphia

The Extension of Long-Distance Telephone Communication, by Bancroft Gherardi. Illustrated with motion pictures. A dinner preceded the meeting. (Complete report on pages 544-5 of July issue) June 11. Attendance 136.

A. I. E. E. Student Activities

BRANCH MEETINGS

University of Detroit

Transformers, by Prof. H. O. Warner. Three reels of motion pictures on the construction and operation of transformers. Appointment of Committee Chairmen. July 10. Attendance 13.

University of Louisville

Refrigeration, by Hugh Nazor, student, and

Application of Electricity to the Steel Industry, by Charles Casper, student. Methods of getting members to attend meetings discussed. June 20. Attendance 9.

The Protection of Transmission Lines Against Lightning, by J. P. Curd, student, and

Lightning Prevention, by George Arehart, student. Discussion on having joint meeting with surrounding branches. August 17. Attendance 19.

Ohio University Branch

Professor A. A. Atkinson, Counselor, reported on the trip taken to power stations in and near Pittsburgh. April 4. Attendance 9.

Talks on manufacture and use of measuring instruments by Representatives of The Weston Electrical Instrument Corp. Several reels of moving pictures, illustrating principles of operation and the construction of instruments. May 9. Attendance 23.

Trip to Philo Plant of the Ohio Power Company and outdoor substation of the Ohio Power Company at Crooksville. May 24. Attendance 16.

STUDENT ACTIVITIES AT THE PACIFIC COAST CONVENTION

Technical Sessions

The first session of the Pacific Coast Convention held at Spokane, Washington, August 28-31, 1928, and reported more fully elsewhere in this issue, was devoted to the presentation of five technical papers by electrical engineering students of the Pacific and North West Districts. In opening the Convention, President Schuchardt referred to the appropriateness of holding an annual convention of the Institute on the Pacific Coast, as Western engineers have written a very important and outstanding chapter in the history of electrical development of the country and the world. He congratulated the Committee upon the excellence of the program and said a somewhat unique and very satisfying feature was the importance given to the Students.

After brief announcements by John B. Fisken, Chairman of the Convention Committee, President Schuchardt requested Professor F. O. McMillan, Chairman of the Committee on Student Activities, North West District, to preside and the following program was presented:

The Phenomena of the Synchronous Breakdown of the Fynn-Weichsel Motor, N. C. Clark, University of California.

The Fynn-Weichsel Motor as a Generator, O. K. Stigers, University of Utah, (Presented by Ned M. Chapman).

The Fynn-Weichsel Motor as a Self-Excited A-C. Generator, Herman Reise, University of Washington.

Electrical Characteristics of Neon-Gas Tubes, G. R. Crane and E. W. Templin, California Institute of Technology, (Presented by G. R. Crane).

Voltage-Ratio Characteristics of Audio-Frequency Transformers Determined by the Cathode-Ray Oscillograph, P. J. Klev, Jr., and D. W. Shirley, Jr., Oregon State Agricultural College, (Presented by P. J. Klev, Jr.).

The Thursday morning session was opened by President Schuchardt who requested Dean Philip S. Biegler, Chairman of the Committee on Student Activities, Pacific District, to preside. The following Student papers were presented:

The Effect of Barriers in Insulating Oil, P. E. Warrington, Stanford University, (Presented by W. G. Snyder).

Temperature Rise due to Eddy Currents in Iron, A. F. Betke and D. R. Stanfield, University of Southern California, (Presented by D. R. Stanfield).

Power Factor and Power Rates, H. B. Tinling, State College of Washington.

The Three-Phase Induction Regulator on Unbalanced Loads, L. W. Curtis, University of Idaho, (Presented by Prof. J. H. Johnson).

In general, the Student papers were very well presented. The attendance throughout the two sessions was approximately 75 to 90, and a large number of those present were practising engineers, the proportion being much larger than usual at Student technical sessions.

Luncheon Conference of Counselors, Branch Chairmen and Institute Officers

Immediately after the technical session on Thursday morning, President Schuchardt, Vice Presidents Northmore and Quinan, Counselors, Branch Chairmen and others interested in Student activities met for a luncheon conference at which Dean C. E. Magnusson of the University of Washington presided. Brief talks on various phases of Student activities were given by all Counselors and Institute officers present.

Conference on Student Activities

A Joint Conference on Student Activities of the Pacific and North West Districts was held on the evening of August 29 and continued on the following morning. Practically all Counselors and Branch Chairmen were present. On account of the cooperation of these two Districts in holding a Pacific Coast Convention each year, the Board of Directors last year approved the plan of holding an annual Joint Conference on Student Activities in connection with the Convention.

Plans for the conference were made under the guidance of Dean P. S. Biegler, University of Southern California, and Professor F. O. McMillan, Oregon State College, Chairman of the Committees on Student Activities of the Pacific and North West Districts, respectively.

The following program was presented:

Branch Programs, Professor R. D. Sloan, Counselor, State College of Washington Branch.

Student Papers, Professor R. W. Sorensen, Counselor, California Institute of Technology Branch.

The Student Branch as an Employment Agency, Professor H. E. Mendenhall, Counselor, University of Utah Branch.

Relations between Branches and Sections, and also, Relations between Branches, Professor T. H. Morgan, Counselor, Stanford University Branch.

The Branch Meeting Attendance Problem, Professor G. L. Hoard, Counselor, University of Washington Branch.

Functions of the Branch Counselor, Dean P. S. Biegler, Counselor, University of Southern California Branch.

What National Headquarters Expects of Branches, Henry H. Henline, Assistant National Secretary.

Opportunity was given for discussion of each topic by Counselors, Branch Chairmen, and others present, and there was a considerable amount of discussion which is summarized briefly below.

It was recommended that the Vice-Presidents of the Pacific and North West Districts call a conference to consider means of promoting employment of engineering students and to develop, wherever feasible, plans for providing for continuous summer employment throughout the college careers of the students. Those present thought local committees sponsored by the Sections and Branches would be very helpful in finding suitable openings for students about to graduate.

Joint meetings and exchange of speakers between Branches and the cooperation with Sections were considered very effective means of stimulating interest among the students.

The advantages of the publication of student papers and the approaching urgent need for some publication outlet for the work of the increasing number of graduate students in electrical engineering were emphasized.

Methods mentioned for improving Branch meetings were: the selection of program material having strong local interest, careful selection of the best time for meetings as determined by other activities of the students, and the development among the students of an understanding of the possibilities of benefit to them which lie in a permanent connection with the Institute as compared with the temporary benefit received from some other extra-curricular activities.

Later in the day the Counselors of the two Districts met separately and elected officers of their respective Committees on on Student Activit asies follows:

Pacific District:

Chairman, Professor T. C. McFarland, University of California.

Secretary, Professor James C. Clark, University of Arizona.

North West District:

Chairman, Professor J. Hugo Johnson, University of Idaho.

PERSONAL MENTION

Irving W. Phillips, formerly electrical engineer with Perry and Whipple, is now with Knight C. Richmond, engineer and architect, Providence, R. I.

Emerson P. Peck, vice-president of the Utica Gas & Electric Co. and Fellow of the Institute, has joined the New York Power and Light Corporation, at Albany, N. Y., as Engineer of Special Studies.

Bernard Lester, assistant industrial sales manager of the Westinghouse Electric and Manufacturing Company, has been placed in charge of the company's business relationships with architects, builders, building contractors, and manufacturers of machinery and motor driven appliances, with headquarters in New York.

Eustace C. Soares, after serving for nearly five years as manufacturing and markets editor of the *Electrical World*, resigned on September 1 to become an officer of the R. B. Engineering Corporation, consulting engineers, New York City. For more than four years prior to joining the staff of the *Electrical World*, Mr. Soares was connected with Ophuls & Hill, Inc., consulting engineers of New York, as electrical engineer in charge of all electrical operations. During that time he designed a number of plants both in the United States and abroad, including the largest ice plant in the World.

Doctor Robert A. Millikan has recently received the Messel Medal, which is awarded every alternate year for the most meritorious scientific work of the two years previous. The last award was to Lord Bâlfour, in 1926. Doctor Millikan received the medal from Francis H. Carr, C. B. E. British president of the Society of the Chemistry Industry.

Carl C. Nelson has resigned from the Westinghouse Electric & Mfg. Company at East Pittsburgh, and has joined the Electric Machinery Manufacturing Company of Minneapolis, Minn.

E. A. Brofos, a member of the Institute since 1907, and vice-president of the International Electric Corporation, has recently been made a Knight, First Class, of the Order of St. Olav by the King of Norway, in recognition of his services to Norwegian industry and public and private telephone communication interests in Norway.

Maurice A. Oudin, vice-president of the International General Electric Company, was the guest of honor at a luncheon given by President Minor of that company at the Bankers Club, New York, September 19. On this occasion, on behalf of the Italian Society of Electrical Engineers, the diploma and insignia of Commander of the Crown of Italy, recently conferred upon him by the King of Italy, was presented to Mr. Oudin by Mr. John W. Lieb.

Obituary

Bernard J. Crahan, an Associate of the Institute since 1917, died June 1928 at the home of his daughter in Detroit, Michigan, at the age of 62. Mr. Crahan was a native of Fulton, New York, receiving his early schooling in Oswego County. He later graduated from the Business University in Detroit, Mich., and there entered the employ of the Detroit City Gas Company, of which he became foreman of construction. After sixteen years of service with this company which distributed natural gas pumped from Canada, Mr. Crahan resigned to accept the general managership of the American Electric Light & Power Company. In 1917 when he joined the Institute, he was general manager of the Port Huron Gas & Electric Company. For 38 years he was active in the public utility field, and for 25 years, managed subsidiary properties for the American Electric Light & Power Company at Joplin, Mo., Portsmouth. Ohio, and Port Huron, Michigan.

Basil F. Howard, electrical engineer of the Mountain States Telephone and Telegraph Company, Denver, Colo., died at his home August 22, 1928.

Mr. Howard was born May 15, 1865, at Croydon, England, the son of an Episcopal vicar. He began his electrical engineering career with telephone interests in England, receiving his first inspiration toward the profession while still at school from a lecture on the telephone, by Prof. Bell. After hearing Professor Bell, Mr. Howard made for himself three pairs of Bell telephones and some Hughes microphones. He also used a condenser as a receiver in connection with these telephones. This was about 1879. He attended lectures and performed laboratory work at the college of the City and Guilds of the London Institute of Technology, Finnsbury, under Professors W. E. Ayrton, F. R. S., and John Perry, in electricity, mechanical engineering and chemistry. Among his early undertakings was the installation of telephones in Buckingham Palace. He developed the telephone industry in England and gained for himself important engineering and operating positions. Coming to America, he became associated with the Colorado Telephone Company, April 1905, and had been successively with that company and its successor, The Mountain States Telephone and Telegraph Company, up to the time of his death, his work lying in the field of transmission and protection. He was well known in the West and in the telephone industry in general as a scientist and engineer of no little ability. Mr. Howard held certificates from the Science and Art Department of the Committee on Her Majesty's Most Honorable Privy Council on Education, Electricity and Magnetism (1880) the College of Preceptors, general education including classics, mathematics, electricity and experimental physics, 1881; (for the papers on electrical engineering Sir Oliver Lodge was the examiner, and full marks were secured); from the London Society for the Extension of University Teach-

ing (Oxford Local Examination) electricity, 1882. He was a member of the Rocky Mountain Chapter No. 8, of the Telephone Pioneers of America, the Royal Photographic Society of Great Britain, the Institution of Electrical Engineers of Great Britain, and the National Electric Light Association. He was active in the Denver Section of the Institute, and his cooperative spirit will be greatly missed.

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York.

All members are urged to notify Institute Headquarters promptly of any changes in mailing or business address, thus relieving the member of needless annoyance and assuring the prompt delivery of Institute mail, through the accuracy of our mailing records and the elimination of unnecessary expense for postage and clerical work.

R. P. Anderson, c/o Elks Club, Chicago, Ill.
Harold L. Biggin, 18 Park Place, Schenectady, N. Y.
C. W. Bohner, 1989 Bedford Ave., Brooklyn, N. Y.
E. P. Bordeaux, 2337 Grand Concourse, New York, N. Y.
Roy J. Campbell, 1515 Mutual St., Sheridan, Pittsburgh, Pa.
Simpson Carno, 8732 20th Ave., Brooklyn, N. Y.
Charles F. Clarke, 1325 Astor St., Chicago, Ill.
Geo. V. Cresson, 128 W. Jersey St., Elizabeth, N. J.
R. S. Datta, P. O. Box 93, S. Milwaukee, Wis.
Geo. A. Daus, 2000 Second Blvd., Rm. 724, Detroit, Mich.
Jos. W. Dowdy, 800 Bush St., San Francisco, Calif.
Monroe E. Epstein, 626 Kirtland St., Pittsburgh, Pa.
Carl F. Faulkner, 842 N. Brand Blvd., Glendale, Calif.
H. H. Force, 626 Chautauga Ave., Norman, Okla.
Robert A. Fraser, 81 Arthur St., East Braintree, Mass.
John J. Gahan, Dimon Court Apts., 1424 Broad St., Columbus, Ohio.
O. M. Hovgaard, Briggs & Stratton Corp., 1047 13th St., Milwaukee, Wis.
W. Homer Love, 112 N. 4th St., Columbus, Ohio.
Daniel J. McDougall, 1239 Ionia St., Los Angeles, Calif.
Russell F. Miller, 57 Prospect Park, S. W., Brooklyn, N. Y.
Gilbert Mitchell, 37 E. 22nd St., New York, N. Y.
Joseph P. Mitchell, 55 Duane St., New York, N. Y.
R. M. Newbold, The Mayflower Apts., Louisville, Ky.
John J. Petruska, 5015 Florence Ave., Philadelphia, Pa.
Frank C. Regina, 1729 13th St., Oakland, Calif.
A. J. Ruel, Western States G. & E. Co., Richmond, Calif.
Paul Scharff, P. O. Box 58, Ridgeway, Pa.
Norman W. Sederberg, 329 Riverdale Ave., Yonkers, N. Y.
Oscar L. Smedberg, 916 12th St., Oregon City, Ore.
H. L. Steinbach, P. O. Box 1002, East Akron, Ohio.
Beverly Thomas, Jr., 8829 Ft. Hamilton Pkwy., Apt. 62B., Brooklyn, N. Y.
John R. Troy, 107 Montague St., Brooklyn, N. Y.
P. V. R. Van Wyck, Summit, N. J.
John J. Zucco, 470 East 161st St., New York, N. Y.

Engineering Societies Library

The Library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES, AUG. 1 TO AUG. 31, 1928

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

Die Abwarmetechnik.

By Hans Balcke. Vol. 2. Munich and Berlin, R. Oldenbourg, 1928. 198 pp., illus., diagrs., 9 x 6 in., cloth. 11,50 M.

The first volume of this work on waste heat engineering discussed the industrial sources of waste heat and the conditions under which it could be utilized profitably for generating steam, heating or distilling. In this second part the constituent parts or plants for utilizing waste heat are described, with the methods of assembling them and connecting them to the heat-producing and heat-utilizing apparatus. The methods of using waste heat in engines, furnaces, feed-water heaters, turbines, etc., are set forth.

Analytische Geometrie der Ebene.

By Robert Haussner. Berlin and Leipzig, Walter de Gruyter & Co., 1928. 164 pp., diagrams, 6 x 4 in., cloth. 1,50 rm.

An introductory textbook on plane analytic geometry, which is intended to give the beginner the general theory of curves of the first and second degrees in full, as well as that for a considerable number of special cases. In spite of extreme condensation the text covers a wide range in a clear manner.

Atomic Structure as Modified by Oxidation and Reduction.

By William Colebrook Reynolds. N. Y., Longmans, Green and Co., 1928. 128 pp., 9 x 6 in., cloth. $3.00.

Starting with the theory that changes in the states of oxidation or reduction cause corresponding alterations in the atomic structures of chemical elements, Dr. Reynolds submits this view to a theoretical investigation, the results of which are recorded

briefly in this book. He advances arguments in support of the theory and discusses the bearing of these changes on the periodic classification, the structure of molecules, solid conductors of electricity and magnets, and upon the properties of chromophores. He advances arguments to prove that the ether is non-homogeneous.

BAHNHOFSANLAGEN, Vol. 1.

By H. Wegele. Berlin and Leipzig, Walter de Gruyter & Co., 1928. 141 pp., diagrs., 6 x 4 in., cloth. 1,50 rm.

Dr. Wegele's book discussed briefly the general planning of railroad stations and terminals, both freight and passenger. Such topics as the situation of stations, the selection of type, the relation of the various parts of stations, track layouts, etc., are treated clearly and concisely. A second volume will treat of buildings.

DIE ANWENDUNG DER INTERFEROMETRIE IN WISSENSCHAFT UND TECHNIK.

By E. Berl and L. Ranis. Berlin, Gebrüder Borntraeger, 1928. (Fortschritte der Chemie, Physik und physikalischen Chemie, Band 19, Heft 7) 52 pp., diagrs., 10 x 6 in., paper. 5,20 m.

The interferometer is finding increasing use in analytical work, particularly in works laboratories where control analyses must be repeated constantly, and where speed and ease of operation, and accuracy, are important. This monograph describes the instrument and calls attention to its various fields of use.

ELEKTRISCHE MESSUNGEN.

By Werner Skirl. Berlin and Leipzig, Walter de Gruyter and Co., 1928. 459 pp., illus., diagrs., 8 x 6 in., cloth. 11 m.

This work forms one of a series of handbooks issued by the Siemens & Halske and the Siemens-Schuckert companies. The handbooks aim to be practical texts and reference books in which the engineer will find a satisfactory account of modern practise.

The book discusses electrical measurements and measuring instruments as simply as possible. Photographs and diagrams are provided in large numbers, and a very complete index is included. The result is an unusually satisfactory book of reference.

ELEKTRISCHE VOLLBAHNLOKOMOTIVEN, ein Handbuch für die Praxis sowie für Studierende.

By Karl Sachs. Berlin, Julius Springer, 1928. 461 pp., plates, diagrs., 11 x 8 in., cloth. 84 rm.

The first work in which the electric locomotive is treated comprehensively. The author, engineer of Brown, Boveri & Cie., has aimed to describe the development and present position of the locomotive in a manner that would be of help to all railroad engineers.

The text falls in four sections. The first discusses the general questions of traction, train resistance, etc. Section two is devoted to the mechanical part of the locomotive, the framework, trucks, and gearing. Special attention is given to gearing and the couplings of motors to drive wheels.

The third section treats of the electrical equipment. Special stress is laid on continuous-current types. The last section describes fifteen actual locomotives, selected from those used on various European railroads. The book should be of decided value to any one interested.

ELEMENTS OF AVIATION, an Explanation of Flight Principles.

By Virginius Evans Clark. N. Y., Ronald Press Co., 1928. 193 pp., diagrs., 9 x 6 in., cloth. $3.00.

This volume, by the chief engineer of the Dayton-Wright Company, is an elementary explanation of the principles of aviation intended for beginners in the industry. It aims to explain the principles of flight without resort to complex mathematics and to discuss the broader considerations of airplane structure and design, and thus to serve as an introduction to further study. An unusually good glossary of aeronautical terms is included.

FORCE ACCOUNT ON UNIT-PRICE CONSTRUCTION CONTRACTS, a report by the Bureau of Municipal Research of Philadelphia.

Philip A. Beatty in charge of this study. Phila., Thomas Skelton Harrison Foundation, 1928. 35 pp., 9 x 6 in., paper. (Copies of the Report may be obtained without charge from the Bureau).

The Bureau of Municipal Research is engaged in a study of the methods followed in Philadelphia in preparing, letting, and performing contracts for municipal work. The present pamphlet presents its finding and recommendations about force-account practises in various departments of the city government.

The pamphlet analyzes practises in some twenty American cities and discusses the advantages and disadvantages of the different methods. Recommendations for controlling force accounts are given. As little has previously been published on this subject, the pamphlet should interest many.

FUNDAMENTAL PRINCIPLES OF ELECTRIC AND MAGNETIC CIRCUITS.

By Fred Alan Fish. 2nd edition. N. Y., McGraw-Hill Book Company, 1928. 212 pp., diagrs., 9 x 6 in., cloth. $3.00.

Professor Fish here sets forth those fundamental principles of circuits which he considers necessary for undergraduate students of electrical engineering. His text is clear and direct and presents the information required as an introduction to the study of electrical machinery and transmission in a brief, teachable form. In this new edition various expansions and rewritings have been adopted.

GEWOLBETABELLEN VEREINFACHUNGEN FUR ENTWURF UND BERECHNUNG STATISCH BESTIMMTER UND UNBESTIMMTER GEWOLBE.

By F. Kögler. 2nd edition. Berlin, Julius Springer, 1928. 104 pp., diagrs., tables, paper. 7,50 rm.

An aid to the designer in calculating statically determinate and indeterminate arches. The book contains tables covering all sizes that are ordinarily used, for all practicable rises and loads. The accompanying text explains the general principles and the application of the tables in the drafting room.

A HANDBOOK OF PETROLEUM, ASPHALT AND NATURAL GAS.

By Roy Cross. (Bulletin No. 25, revised) Kansas City, Mo., Kansas City Testing Laboratory, 1928. 832 pp., tables, diagrs., 7 x 5 in., leather. $7.50.

A very convenient pocket-book for oil men and others interested in petroleum. The author has brought together in condensed form a great mass of technical and scientific information on the production, properties, handling, refining, and evaluating petroleum, asphalt, natural gas, and oil shale. Particular attention is paid to refining and cracking. A valuable list of patents on cracking is included, and there is a good bibliography. The present publication is a revision of earlier issues, with additions.

JAHRBUCH DER ELEKTROTECHNIK, 1926.

Edited by Karl Strecker. Munich and Berlin, R. Oldenbourg. 1928, 268 pp., 9 x 6 in., cloth. 16 m.

This year book, which is subsidized by the German electrical engineering industry, aims to give a concise account of all important data and occurrences which have been published in the periodicals of the year. The volume at hand covers the year 1926.

The material is classified into numerous divisions, and the account of each subject is prepared by a specialist. About 250 sources have been examined. References to originals are given and good author and subject indexes are provided.

Lehrbuch der Physikalischen Chemie.

By Karl Jellinek. 2nd edition. Stuttgart, Ferdinand Enke, 1928. Diagrams, 10 x 6 in., paper. Vol. 1, 82 m.; Vol. 2, Lieferung 1, 21 m., Lieferung 2, 24 m.

In 1914 Dr. Jellinek published the first volume of his "Lehrbuch," which was planned to cover the entire subject uniformly and comprehensively. A second volume appeared in 1915, but publication was then stopped by the World War, and the parts issued have long been out of print.

Research students of physics and chemistry will therefore welcome the resumption of the work. Volume one and part of volume two are now ready, in an entirely rewritten second edition, and completion of the work, in five volumes, is planned by 1931. As the only comparable work, Ostwald's "Lehrbuch," is twenty-five years old, the new treatise is bound to become an indispensable work of reference for all workers in this field.

Die Physikalischen Grundlagen der Elektrischen Festigkeitslehre.

By N. Semenoff and Alexander Walther. Berlin, Julius Springer, 1928. 168 pp., diagrs., tables, 9 x 6 in., cloth. 16,50 rm.

The Physico-Technical Laboratory at Leningrad has been engaged for several years in investigating certain questions about the electrical properties of dielectrics. In the present volume the assistant director and the engineer of the Laboratory report on the results obtained.

The book contains three sections. In the first are described in detail the experimental methods adopted by the Institute for measuring electrical fields with exactness. The second section treats of the vacuum as an insulant and gives a systematic review of our knowledge on this point. Section three discusses the breaking down of solid insulants, treating of the electrical properties of dielectrics, the various theories of breakdown, the experiments made, and the conclusions derived.

Protection Contre Les Effets Nuisibles de L'Electricite.

By F.-G. de Nerville and A. Hardy. Paris, J.-B. Ballière et Fils, 1928. 860 pp., illus., diagrs., 9 x 6 in., paper. 125 fr.

The accidents and disturbances due to electricity are discussed quite fully in this volume, which aims to describe all the injurious effects that electricity may cause, and the methods of preventing them.

The first portion of the book discusses dangers to the individual. The physiological effects of electricity are described, after which methods of protection from lightning and from accidents due to electrical currents are treated. The injurious effects of stray earth currents are then considered, with the remedies. The final section is concerned with disturbances in telephone and telegraph lines caused by other conductors.

Solubilities of Inorganic and Organic Compounds, A Compilation of Quantitative Solubility Data from the Periodical Literature.

By Atherton Seidell. Supplement to the second edition. N. Y., Van Nostrand Co., 1928. 569 pp., tables, 9 x 6 in., cloth. $8.00.

Dr. Seidell has brought his useful compendium of solubilities up to date by publishing a supplement to the second edition which contains the data published during the decade 1917-1926.

The volume adheres to the previous plan. The compiler has endeavored to select the most reliable data and to meet the more important needs of all classes of chemists. It gives references to the sources of the information and contains an index covering both the present volume and its predecessor. The two volumes make readily available a vast amount of important matter without laborious searching.

Die Symbolische Behandlung der Wechselstrome.

By Gerhard Hauffe. Berlin and Leipzig, Walter de Gruyter & Co., 1928. 102 pp., 6 x 4 in., cloth. 1,50 rm.

A very concise textbook which aims to facilitate the use of the symbolic method, as introduced by Steinmetz, in electrical engineering. Starting with an exposition of the mathematical principles involved, the application of the method to resistance operations is developed, especially in electrical measurements.

Technisches Hilfsbuch.

Edited by Schuchardt & Schütte. 7th ed. Berlin, Julius Springer, 1928. 526 pp., illus., tables, diagrs., 7 x 5 in., cloth. 8 rm.

A pocket book for machinists and mechanical engineers, which gives in convenient form much information on standards for screw threads and machine parts, on the properties of metals and the capacities of machine tools, and on shop practise in general. The work is an unusually well selected collection of data.

Technisches Hilfsbuch der Osterreichisch-Alpinen Montangesellschaft.

Vienna, Julius Springer, 1928. 66 pp., tables, plates, diagrs., 7 x 5 in., paper. 3,60 rm.

A small pocket-book containing tables and formulas frequently wanted by mining and metallurgical engineers. The data include the chief mathematical, chemical, and physical constants, selected with the needs of Austrian engineers in mind.

Traite-Pratique de Navigation Aerienne.

By A-B. Duval and L. Hébrard. Paris, Gauthier-Villars & Cie., 1928. 196 pp., diagrs., plates, 10 x 7 in., paper. 30 fr.

Duval and Hébrard's Practical Treatise on Aerial Navigation was, we believe, the first to appear on that subject. Originally printed serially in "L'Aéronautique" several years ago, it later appeared in book form. The second edition is now published, with revisions bringing it up to date.

The book presents the technical methods of navigation, as adapted from those which maritime navigators have found satisfactory. The treatment is elementary. The use of the compass and other instruments is explained, the general rules of navigation are given, and methods are outlined.

Visual Lines for Spectrum Analyses.

By D. M. Smith. Lond., Adam Hilger, Ltd., 1928. 34 pp., 8 x 5 in., cloth. 5s.

The publisher of this booklet manufactures a wave length spectrometer which enables metals present in various substances, as constituents or impurities, to be identified rapidly and easily. The present publication gives the necessary tables of wavelengths, describes the technique of the process, and shows various applications of the method in chemical and metallurgical analysis.

Die Wanderwellenvorgange auf Experimenteller Grundlage.

By Ludwig Binder. Berlin, Julius Springer, 1928. 200 pp., illus., diagrs., 9 x 6 in., paper. 22 rm.

This volume, by the Director of the Institut für Elektromaschinenbau at the Dresden Technical High School, presents a connected account of the investigations of transient phenomena in electric lines and machines. The questions which have been investigated experimentally and which are reported include such major ones as the steepness of the wave-fronts of surges, the mode of transmission of surges along lines, the tensions in coils that they may produce, the effectiveness of protective apparatus, and the behavior of insulating materials subjected to short strains.

Water Purification.

By Joseph Ellms. 2nd edition. N. Y., McGraw-Hill Book Co., 1 28. 594 pp., illus., tables, plates, diagrs., 9 x 6 in., cloth. $3.00.

A comprehensive treatise on the purification of water by an engineer of wide experience. The entire subject is covered, and practical information is given on the design, construction, and operation of filtration plants, and costs are included freely. Bibliographic references are provided amply.

The new edition, which is about one-fourth larger than the first, has been carefully revised and brought up to date. A new chapter on the effect of the hydrogen-ion concentration of natural waters has been added.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contributions from the societies and their individual members who are directly benefited.

Offices:—31 West 39th St., New York, N. Y.,—W. V. Brown, Manager.
1216 Engineering Bldg., 205 W. Wacker Drive, Chicago, Ill., A. K. Krauser, Manager.
57 Post St., San Francisco, Calif., N. D. Cook, Manager.

MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 31 WEST 39th Street, New York City,*** *and should be received prior to the 15th day of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by contributions made within thirty days after placement, on the basis of one and one-half per cent of the first year's salary; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

DESIGNING ENGINEER, thoroughly competent, for manufacturer of high-grade radios. Must have record of successful accomplishments. Apply by letter, giving complete details of experience and personality. Location, New England. X-5978.

ELECTRICAL DEVELOPMENT OR RESEARCH ENGINEER, preferably with experience in the commercial development of control apparatus. Must be a technical graduate also practical experience in the application of electric motors or motor control apparatus very desirable. Most important that he be equipped with good judgment and imagination. Would eventually take charge of experimental and research department. Opportunity. Apply by letter, stating details of previous experience and compensation expected. Location, Middlewest X-5792-C.

SERVICE ENGINEER, young, with knowledge of rotary converters and generators. Electrical engineering graduate with test bed experience preferred. Apply by letter, giving full particulars, experience, age, qualifications, and salary required. Location, New York. Will be required to travel. X-5833.

DESIGNING AND RESEARCH ENGINEER, young, capable of taking charge of development and research laboratory. Must have good educational training and possess laboratory skill. Opportunity. Apply by letter. Location, Chicago. X-5834-C.

TRANSFORMER DESIGNER AND ENGINEER, to take full technical control of the manufacture and design of any kind of power transformer. Apply by letter, giving age, education, experience in detail, salary desired, and availability. Location, England. X-5916.

GRADUATE ELECTRICAL ENGINEERS, two, young, with 2-3 years' power company experience; one in transmission construction and operation; the other in station construction and operation. Good personality and commercial or sales inclination is necessary, as these men will be thoroughly and carefully trained for sales work by a well-known, substantial manufacturer. Opportunity. Apply by letter, giving complete personal details, as well as experience, salary required, etc. Location, Middle West. X-5883-C.

MEN AVAILABLE

TECHNICAL GRADUATE, married, G. E. test, broad experience United States and Mexico, mechanical and electrical construction, operation, maintenance, coal and metal mine pumping, hoisting, haulage, treatment plant equipment; also generation, transmission, utilization of steam, air and electric power. Desires mining or industrial position; location immaterial, but Spanish America preferred. B-8872.

SUBSTATION ENGINEER, graduate in E. E. 1½ years G. E. test. Five years' utility experience includes system operation and maintenance; substation inspection, test, construction, design; budget and estimating work. Has specialized on relay and control problems. References as to ability and character from former employers are available. Two weeks' notice required. B-9514.

GRADUATE ELECTRICAL ENGINEER, 24, single. One year's experience in mining electrical engineering. Various electrical maintenance positions held in last four years with large companies. Capable of mining executive position. Experience in designing and planning electrical construction. Location preferred, Middle West. C-4996.

ELECTRICAL ENGINEER-ESTIMATOR, 31, graduate, 9 years' experience; 2 years with architect layouts and specifications, light, power signals for theaters, hotels, apartments, etc. One year with contractor, directing and engineering work from office on new buildings. Desires connection with contractor, architect, or consulting engineer anywhere in United States. B-4217.

EXECUTIVE, graduate engineer, fifteen years' experience, construction, operation, management; mostly electric light and power public utilities. Schooled by a financial leader of the industry, especially in reduction of operating expenses. Knowledge of state regulatory requirements. Would be interested in holding company appointment. Preferably salary plus percentage of effected savings per annum. B-1003.

ELECTRICAL ENGINEER, M. I. T. '26, desires position with construction or industrial firm. Has had two years generating and substation estimating, cost analysis and construction work in the field. Speaks German and French. Employed at present. Location, anywhere, but preferably Philadelphia. C-4983.

EXECUTIVE, with technical training, desires position with manufacturing organization. Experienced in sales engineering and manufacturing of electrical equipment. Also experienced as field engineer on installation of electrical equipment for central steam stations including substations. Prefer South or Middle West locations. B-9039.

ELECTRICAL ENGINEER AND EXECUTIVE, 47, graduate E. E., with 16 years' manufacturing experience and 8 years' experience in industrial and office building layout and construction. Now located in Los Angeles, and wishes position with headquarters in South West. B-3256.

ELECTRICAL ENGINEER, 25, single. University graduate, B. S. in E. E. Desires position with an electrical manufacturer or a public utility. Two years General Electric test. Location preferred, Central East. Now employed. C-4965.

EXECUTIVE OR ELECTRICAL ENGINEER, 40, married. 14 years' experience covering design, construction and maintenance distribution and transmission systems, substations and generating stations, equipment sales, purchases, statistics and special reports. Desires connection with public utility or manufacturing concern. Southern or Central States preferred. B-9480.

ELECTRICAL ENGINEER, having 8 years' practical experience on transmission, distribution, testing and sales work, is desirous of a connection with progressive concern. Willing to accept position in Europe. B-7412.

ASSISTANT TO ENGINEER OR SUPERINTENDENT, electrical and mechanical engineer with nine years' experience in responsible position in the installation, testing, operation and maintenance of generating and substation equipment of large public utility. Also experienced in industrial plants and general engineering. Has initiative, ability and can secure results. C-2456.

ELECTRICAL ENGINEERING GRADUATE, seven years' experience as follows: Six months maintaining power station electrical equipment. Six months testing and installing meters. Three years of substation maintenance, operation, protection and checking. One year distribution, operation, and maintenance. Two years transmission engineering and designing. Engineering, construction, or maintenance position desired. C-5013.

ELECTRICAL ENGINEER, 31, graduate, Norwegian. Two years' experience in substation, power plant equipment, such as shop work on power transformers, relay testing, structure, switchboard diagrams. 1½ years' experience electrical engineer, Westinghouse, electric locomotive equipment. Desires position engineering department public utility company or electric railway concern. Speaks French, German. Excellent references. C-4942.

RECENT GRADUATE, S. B. in E. E., M. I. T., (1927) 22, single, desires position in commercial field. One year's experience as instructor in large western university. Can furnish excellent references. Location preferred, East. C-3550.

GRADUATE, 26, single, with B. S. in E. E. and 3 years' experience testing electric meters, wants work in engineering, with chance for advancement. Available immediately. Location, immaterial. C-5028.

GRADUATE ELECTRICAL ENGINEER, 22, B. S. in E. E. 1928, single, desires position with public utility or industrial concern. Good character and personality, reliable and industrious. Available at once. C-4973.

ELECTRICAL ENGINEER, 29; 4 years iron and steel works electrical installation and maintenance; 3 years electrical erection for electrical manufacturing company; 2 years oil fields electrification and 3 years electrical drafting; design of central and substation electrical plant; switch boards and switchgear, etc. C-625.

STEAM ELECTRICAL ENGINEER, open for a position as superintendent of office building or power plant or master mechanic. American, married. Has had 25 years' experience, covering maintenance and operation. Good organizer, able to handle men. Can furnish excellent reference as to character and ability. Available on short notice. Salary open to negotiation. C-5032.

ELECTRICAL ENGINEER, 25, University graduate, 1926, with degree of B. S. in E. E., 2 years' experience in manufacturing and d-c. design, desires position in development, experimental or design work. Position must be permanent and have possibilities for advancement. Now employed. Available on reasonable notice. Location preferred, Middle West. C-5030.

ELECTRICAL ENGINEER, 29, married. Technical university graduate, 6 years' experience in testing, designing, manufacturing, estimating, etc., of electrical apparatus. Desires position with public utility or manufacturing concern. Location preferred, Middle West. C-5039.

INDUSTRIAL ELECTRICAL ENGINEER, graduate '21, 31, married, seeks connection with future. Experience covers design and layout of entire electric system in largest Canadian Paper Mills, including hydroelectric power plants, also steel mill electrification, utility networks and smaller industrial installations. Available on reasonable notice. C-5038.

ENGINEER-STATISTICIAN, Electrical Engineer, 29, E. E. Zurich, Switzerland; Master of Business Administration, New York University. Six years' experience in distribution systems, electrical equipment for industrial uses, projecting, electrical calculation, costanalysis; thorough knowledge of statistical methods, economics, accounting, costaccounting, financial organization and management. Reference. Minimum salary $5000. Married. Location, immaterial. C-4989.

RESEARCH ENGINEER, 32, M. I. T. graduate, M. S. in E. E.; six years' experience with power companies on important test and investigation work; five years in the research department of prominent manufacturer on research and development work. Available on short notice. B-1041.

ELECTRICAL ENGINEER, graduate, desires position with public utility or industrial firm. Two years Westinghouse test. Five years electrical design and construction of power plants, substations and industrial layouts. Three years as assistant to electrical engineer of industrial company. Would like a connection with an opportunity. B-8379.

ASSISTANT EXECUTIVE OR DEPARTMENT HEAD, married, 33. Engineering and Arts graduate, with budgeting, scheduling, statistical, valuation rate study, operating, construction and some design experience; available for position with operating, holding or manufacturing company. Eleven years' experience; seven years utility, four years industrial. B-9676.

ELECTRICAL ENGINEER, 25, single. B. S. in E. E., 1924 with four years' industrial experience, desires permanent position with consulting firm or industrial organization. Location preferred, New York or vicinity. B-8400.

ELECTRICAL AND MECHANICAL ENGINEER, 45, married. 27 years' experience in the construction and maintenance of high- and low-tension central power and substation equipment, industrial and marine diesel-electric plants. A supervisor of mechanics in all trades. Excellent references. Now employed, available at reasonable notice. B-721.

METER ENGINEER, 28, single. Understand the testing, repair and installation of all types of watthour, demand and combination meters; testing and calibrating of standards; instrument transformer installation and testing; meter records. Foreman of meter department since 1919. C-2831.

ENGINEER, married, experienced in layout, supervision of construction and operation of electrical and mechanical equipment in mills and factories. Practical experience in steel mills, powder plants, some railroad work and a good experience on hoisting and conveying machinery. Desires position preferably within a commuting distance of Ridgewood, N. J. B-5068.

ELECTRICAL ENGINEER, graduate, 22, single, and in A-1 health, good draftsman, sales personality and a year's experience on Westinghouse Test, desires a permanent position with a public utility, mining or manufacturing company. Willing to start on a moderate salary. Location, immaterial. Excellent references. Available on two weeks' notice. C-3678.

ELECTRICAL MECHANICAL ENGINEER, graduate, 25, single. One year Business Administration Course. two years' experience in Electrical Railroad, Power Stations, construction, testing, design. At present connected with consulting engineers doing railroad evaluation. Speaks French, German, Spanish. Location, South America or Europe. C-4892.

ELECTRICAL ENGINEER, 1922 graduate, with B. S. degree in Commerce, also. 30, widower with two children. Experience in motor manufacturer's test department. Broad experience in large electrical pulbic utility, including modern power plant, substations, power sales department, supervision of engineering of electric meter and testing laboratory. Seeking better position. C-4995.

ELECTRICAL MECHANICAL ENGINEER with chemical experience; Technical University graduate, 18 years manager of experiment station; telegraphy, telephony, radio. Desires position in research department, rapid and picture telegraphy, telephony on telegraph wires, ocean cable telephony, noise abatement, wants to perfect his Television in Colors system. B-7707.

ELECTRICAL ENGINEER, American, married. Broad experience designing, constructing power and industrial plants, substations, distribution and transmission lines. Supervised engineering of large electrical projects and pulverized fuel systems. Made special studies in cable research, high frequency radiation. Prepared reports, estimates and specifications for light, power. Thoroughly qualified executive with international reputation. B-3954.

JUNIOR ELECTRICAL ENGINEER, 24, single, graduate, 1926, desires position with growing public utility or hydroelectric development which has opportunity for advancement. Experience includes two years civil engineering, power plant designing; last two years on all types of general test work with large public utility. For the past year in a supervisory capacity. C-2667.

CHIEF ELECTRICIAN, 31, single. Graduate Bliss Electrical School; 14 years' experience in electrical maintenance, repair and test. Three years in charge of all electrical construction and maintenance work in 180,000-kw. steam generating plant. Location preferred, West. C-5068.

ENGINEERING EXECUTIVE. Twenty years' experience in design and manufacture of electrical apparatus. At present and for past six years chief engineer of nationally known company. Familiar with problems of development, production, purchasing, cost and sales. Desires change to larger company with broader outlook. St. Louis or middle west locality preferred. C-5062.

GRADUATE ELECTRICAL ENGINEER, 24, single, desires position in application or design of small motors. One year on Westinghouse Student Course; six months in Westinghouse Design School; one and one-half years on design and construction of small motors. Available on short notice. Location, United States, east preferred. C-5051.

ELECTRICAL MECHANICAL ENGINEER, graduate M. I. T. Two years' experience in manufacture, production, development and design of small motors; a-c. rectifiers for radio and commercial use. Two years development work and manufacturing, planning with large corporation in telephone industry, with background of field work in automatic telephony. Desires responsible position requiring initiative. C-1305.

(See also pp. 33 and 40 of Advertising Section).

MEMBERSHIP—Applications, Elections, Transfers, Etc.

APPLICATIONS FOR TRANSFER

The Board of Examiners, at its meeting held September 26, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the National Secretary.

To Grade of Fellow

CHARLESWORTH, HARRY P., Plant Engineer, American Tel. & Tel. Co., New York, N. Y.

CRELLIN, EARLE A., Assistant Engineer, Pacific Gas & Electric Co., San Francisco, Calif.

DENTON, FRANCIS MEDFORTH, Associate Professor of Electrical Engineering and Physics, State University of New Mexico, Albuquerque, New Mexico.

HORTON, J. WARREN, Member of Technical Staff, Bell Telephone Laboratories, New York, N. Y.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before October 31, 1928.

Attwood, F. L., American Tel. & Tel. Co., New York, N. Y.

Bacon, D. C., Southwestern Bell Telephone Co., Dallas, Texas

Bakeman, C. T., Puget Sound Power & Light Co., Seattle, Wash.

Baker, R. M., Baker's Shop, Bellevue, Ohio

Banks, H. P., Public Service Production Co., Newark, N. J.

Barnes, M. T., Texas-Louisiana Power Co., Williamstown, Ky.
Barr, A. A., Caliente Public Utilities, Caliente, Nev.
Bausch, E., New York Rapid Transit Corp., Brooklyn, N. Y.
Berger, D., Kiemle Motor Co., Toledo, Ohio
Bon, C. H., Stromberg-Carlson Tel. Mfg. Co., Rochester, N. Y.
Brashear, H. E., Southwestern Bell Telephone Co., Dallas, Texas
Brown, P. C., Whitehall Cement Mfg. Co., Cementon, Pa.
Chilton, W. J., Southwestern Bell Telephone Co., Dallas, Texas
Curtis, L. E., Jr., Pennsylvania Power & Light Co., Allentown, Pa.
Duff, D., Pacific Electric Mfg. Corp., San Francisco, Calif.
Dunlap, J. P., Electrical Engineers Equipment Co., Melrose Park, Ill.
Farster, M. E., Electrical Research Products, Inc., New York, N. Y.
Ferguson, L. A., Jr., (Member), Commonwealth Edison Co., Chicago, Ill.
Flagg, P. M., Pacific Tel. & Tel. Co., Seattle, Wash.
Gabler, R. T., Copperweld Steel Co., Glassport, Pa.
Griesmann, W. J., Brooklyn Edison Co., Brooklyn, N. Y.
Heafer, H. P., Southwestern Bell Telephone Co., Dallas, Texas
Humphrey, D. G., The Toledo Edison Co., Toledo, Ohio
Kiemle, F. W., F. W. Kiemle Co., Toledo, Ohio
Lien, G. O., Westinghouse Elec. & Mfg. Co., New York, N. Y.
Lim, V. F., Interborough Rapid Transit Co., New York, N. Y.
Littman, L., Polymet Mfg. Corp., New York, N. Y.
Matthews, C. G., Graybar Electric Co., Dallas, Texas
Michas, C. D., New York Edison Co., New York, N. Y.
Miles, W. E., Naval Radio Communications, Boston, Mass.
Mittanck, E. H., Southwestern Bell Telephone Co., Dallas, Texas
Myers, T. G., (Member), U. S. Electrical Mfg. Co., Los Angeles, Calif.
Naiman, S., Naiman & Co., Asheville, N. C.
Newman, A., Jr., Electric Specialty Co., Stamford, Conn.
Payette, S. A., Puget Sound Power & Light Co., Seattle, Wash.
Pennefeather, J. E., Scranton, Montrose & Binghamton R. R., Scranton, Pa.
Perrot, S. A., British Columbia Electric Co., Vancouver, B. C., Can.
Porter, W. E., (Member), General Electric Co., West Lynn, Mass.
Poulsen, I. C., Southwestern Bell Telephone Co., Dallas, Texas
Ranklin, R. H., Fordson Coal Co., Stone, Ky.
Reeve, J. D., Koppers Construction Co., Pittsburgh, Pa.
Reeves, D. W., Gulf States Utilities Co., Lake Charles, La.
Sabbah, H. C. A., (Member), General Electric Co., Schenectady, N. Y.
Schatzel, R. A., Rome Wire Co., Rome, N. Y.
Shaffer, F. E., Central Gas & Electric Corp., Poughkeepsie, N. Y.
Terry, W. A., Jr., Koppers Construction Co., Pittsburgh, Pa.
Tiedeman, J. A., General Electric Co., Schenectady, N. Y.
Tormo, M. G., Grand Central Station, New York, N. Y.
Willis, E. N., (Member), Southwestern Public Service Association, Dallas, Texas
Woolsey, C. L., Pacific States Electric Co., Seattle, Wash.
Wu, K. C., c/o City National Bank of New York, New York, N. Y.
Yeager, R. F., Southwestern Bell Telephone Co., Dallas, Texas
Total 52.

Foreign

Bhagwan, B. K., Power House & Mains, Aurangabad, Deccan, India
Brakenridge, W. D., Metropolitan-Vickers Electrical Co., Manchester, Eng.
Dannatt, C., Metropolitan Vickers Elec. Co., Ltd., Manchester, Eng.
Herring, E. J. C., (Member), Jost's Engineering Co., Bombay, India
Mahoney, L. G. P., Mangaweka Town Board, Mangaweka, N. Z.
Ramakrishnan, S., Victoria Jubilee Technical Institute, Matunga, Bombay, India
Sharma, M. D., N. W. Railway, Gwalmandi, Lahore, India
Watkins, W. A., Municipal Council of Sydney, Sydney, N. S. W., Australia
Venkatram, K. S., Ahmedabad Electricity Co., Ahmedabad, India
Total 9.

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Charles le Maistre, 28 Victoria St., London, S. W. 1, England.
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Guido Semenza, 39 Via Monte Napoleone, Milan, Italy.
P. H. Powell, Canterbury College, Christchurch, New Zealand.
Axel F. Enstrom, 24a Grefturegatan, Stockholm, Sweden.
W. Elsdon-Dew, P. O. Box 4563, Johannesburg, Transvaal, Africa.

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(A list of the personnel of Institute committees may be found in the September issue of the Journal.)

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Standards, F. D. Newbury
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Applications to Marine Work, W. E. Thau
Applications to Mining Work, Carl Lee
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Research, F. W. Peek, Jr.
Transportation, W. M. Vandersluis

A. I. E. E. REPRESENTATION

(The Institute is represented on the following bodies; the names of the representatives may be found in the September issue of the Journal.)

American Association for the Advancement of Science, Council
American Bureau of Welding
American Committee of Electrolysis
American Engineering Council
American Engineering Standards Committee
American Marine Standards Committee
American Year Book, Advisory Board
Board of Trustees, United Engineering Society
Charles A. Coffin Fellowship and Research Fund Committee
Committee of Apparatus Makers and Users, National Research Council
Committee on Elimination of Fatigue, Society of Industrial Engineers
Committee on Heat Transmission, National Research Council
Engineering Foundation Board
John Fritz Medal Board of Award
Joint Committee on Welded Rail Joints
Joint Conference Committee of Four Founder Societies
Library Board, United Engineering Society
National Fire Protection Association, Electrical Committee
National Fire Waste Council
National Research Council, Engineering Division
National Safety Council, Electrical Committee of Engineering Section
The Newcomen Society
Radio Advisory Committee, Bureau of Standards
Society for the Promotion of Engineering Education, Board of Investigation and Coordination
U. S. National Committee of the International Commission on Illumination
U. S. National Committee of the International Electrotechnical Commission
Washington Award, Commission of

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Baltimore	W.B.Kouwenhoven	R. T. Greer, Cons. Gas Elec. Lt. & Pr. Co., Lexington Bldg., Baltimore, Md.
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Cleveland	E. W. Henderson	P. D. Manbeck, National Carbon Co., Madison Ave. & West 117th St., Cleveland, Ohio
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Lehigh Valley	H. D. Baldwin	E. F. Weaver, Pa. Pr. & Lt. Co., 901 Hamilton St., Allentown, Pa.
Los Angeles	H. L. Caldwell	N. B. Hinson, Southern Cal. Edison Co., 3rd and Broadway, Los Angeles, Cal.
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Lynn	Charles Skoglund	V. R. Holmgren, Turbine Engg. Dept., G. E. Co. Bldg. 64 G, Lynn, Mass.
Madison	L. J. Peters	L. C. Larson, Dept. of Elec. Engg., University of Wisconsin, Madison, Wisconsin
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Milwaukee	E. R. Stoekle	R. R. Knoerr, Engr., Knoerr & Fischer, 553 Milwaukee St., Milwaukee, Wis.
Minnesota	M. E. Todd	V. E. Engquist, Northern States Pr. Co., Rice & Atwater Streets, St. Paul, Minn.
Nebraska	C. D. Robison	
New York	R. H. Tapscott	H. S. Sheppard, Dept. of Dev. & Research, Amer. Tel. & Tel. Co., 195 Broadway, New York, N. Y.
Niagara Frontier	G. H. Calkins	E. P. Harder, Buffalo General Electric Co., 205 Electric Bldg., Buffalo, N. Y.
Oklahoma	C. V. Bullen	C. W. Walter, Dept. of Elec. Engg., Univ. of Oklahoma, Norman, Okla.
Panama	L. W. Parsons	M. P. Benninger, Box 174, Balboa Heights, C. Z.
Philadelphia	L. F. Deming	R. H. Silbert, Philadelphia Electric Co., 2301 Market St., Philadelphia, Pa.
Pittsburgh	H. E. Dyche	J. A. Cadwallader, The Bell Telephone Co. of Pa., 416 7th Ave., Pittsburgh, Pa.
Pittsfield	J. R. Rue	V. M. Montsinger, General Electric Co., Pittsfield, Mass.
Portland, Ore.	L. M. Moyer	H. H. Cake, Pacific State Elec. Co., 5th and Davis Streets, Portland, Ore.
Providence	A. E. Watson	F. W. Smith, Blackstone Valley Gas & Elec. Co., Pawtucket, R. I.
Rochester	H. E. Gordon	C. F. Estwick, c/o General Railway Signal Co., Rochester, N. Y.
St. Louis	C. P. Potter	E. G. McLagan. 2188 Railway Exchange Bldg., St. Louis, Mo.
San Francisco	B. D. Dexter	A. G. Jones, General Electric Co., 804 Russ Bldg., San Francisco, Calif.
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Schenectady	E. S. Lee	E. E. Johnson, Room 435, Bldg. No. 2, General Electric Co., Schenectady, N. Y.
Seattle	C. R. Wallis	Ray Rader, Puget Sound Pr. & Lt. Co., Seattle, Wash.
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Spokane	Bernhard Olsen	H. L. Vincent, General Electric Co., 402 Paulsen Bldg., Spokane, Wash.
Springfield, Mass.	J. F. Murray	B. V. K. French, Am. Bosch Magneto Corp., Springfield, Mass.
Syracuse	W. R. McCann	F. E. Verdin, 614 City Bank Bldg., Syracuse, N. Y.
Toledo	W. T. Lowery	Max Neuber, 1257 Fernwood Ave. Toledo, Ohio
Toronto	E. M. Wood	W. F. Sutherland, Toronto Hydro Elec. System, 225 Yonge St., Toronto, Ont., Canada
Urbana	J. K. Tuthill	M. A. Faucett, University of Illinois, 301-A Elec. Engg. Laboratory, Urbana, Ill.
Utah	C. B. Shipp	A. C. Kelm, 133 So. West Temple St., Salt Lake City, Utah
Vancouver	C. W. Colvin	J. Teasdale, British Columbia Elec. Railway Co., Vancouver, B. C., Canada
Washington	L. D. Bliss	R. W. Cushing, Federal Pr. Comm., Interior Bldg., 18th & F Sts., N. W., Washington, D. C.
Worcester	A. F. Snow	F. B. Crosby, Morgan Constr, Co., 15 Belmont St., Worcester. Mass.
Total 53		

LIST OF BRANCHES

Name and Location	Chairman	Secretary	Counselor (Member of Faculty)
Akron, Municipal University of, Akron, Ohio	C. D. Tinley	P. W. Bierman	J. T. Walther
Alabama Polytechnic Institute, Auburn, Ala	W. P. Smith	C. W. Meyer	W. W. Hill
Alabama, University of, University, Ala			
Arizona, University of, Tucson, Ariz	J. H. Hopper	Audley Sharpe	J. C. Clark
Arkansas, University of, Fayetteville, Ark	W. H. Mann, Jr.	Dick Ray	W. B. Stelzner
Armour Institute of Technology, 3300 Federal St., Chicago, Ill	L. J. Anderson	H. T. Dahlgren	D. P. Moreton
Brooklyn Polytechnic Institute, 99 Livingston St., Brooklyn, N. Y	H. F. Steen	F. J. Mullen	
Bucknell University, Lewisburg, Pa	R. E. Snauffer		W. K. Rhodes
California Institute of Technology, Pasadena, Calif	G. R. Crane	A. W. Dunn	R. W. Sorensen
California, University of, Berkeley, Calif	H. H. Hyde	H. K. Morgan	T. C. McFarland
Carnegie Institute of Technology, Pittsburgh, Pa	G. M. Cooper	J. H. Ferrick	B. C. Dennison
Case School of Applied Science, Cleveland, Ohio	W. A. Thomas	J. O. Herbster	H. B. Dates
Catholic University of America, Washington, D. C			
Cincinnati, University of, Cincinnati, Ohio	C. E. Young	W. C. Osterbrock	W. C. Osterbrock
Clarkson College of Technology, Potsdam, N. Y		C. H. Joy	A. R. Powers
Clemson Agricultural College, Clemson College, S. C	A. P. Wylie	W. J. Brogdon	S. R. Rhodes
Colorado State Agricultural College, Fort Collins, Colo			H. G. Jordan
Colorado, University of, Boulder, Colo	H. R. Arnold	E. E. Stoeckly	W. C. DuVall
Cooper Union, New York, N. Y	E. T. Reynolds	Wilfred Henschel	
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Detroit, University of, Detroit, Mich	E. T. Faur	Wm. F. Haldeman	H. O. Warner
Drexel Institute, Philadelphia, Pa	D. M. Way	C. W. Kenyon	E. O. Lange
Duke University, Durham, N. C	W. E. Cranford	C. W. Berglund, Jr.	W. J. Seeley
Florida, University of, Gainesville, Fla	A. W. Payne	N. J. Rogers	J. M. Weil
Georgia School of Technology, Atlanta, Ga	E. M. Burn	K. W. Mowry	E. S. Hannaford
Idaho, University of, Moscow, Idaho	O. C. Mayer		J. H. Johnson
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Iowa, State University of, Iowa City, Iowa	F. L. Kline	M. B. Hurd	A. H. Ford
Kansas State College, Manhattan, Kansas	H. C. Lindberg	J. E. Schwanke	R. G. Kloeffler
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Kentucky, University of, Lexington, Ky	H. M. Otto	D. M. James	W. E. Freeman
Lafayette College, Easton, Pa	J. W. Dagon	H. W. Lovett	Morland King

LIST OF BRANCHES—*Continued.*

Name and Location	Chairman	Secretary	Counselor (Member of Faculty)
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Louisville, University of, Louisville, Ky	Samuel Evans	J. S. Overstreet	D. C. Jackson, Jr.
Maine, University of, Orono, Maine	A. V. Smith	G. A. Whittier	W. E. Barrows, Jr.
Marquette University, 1200 Sycamore St., Milwaukee, Wis	P. C. Neumann	W. E. Schmitz	J. F. H. Douglas
Massachusetts Institute of Technology, Cambridge, Mass	R. M. Durrett		W. H. Timbie
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Michigan, University of, Ann Arbor, Mich	W. R. Hough	H. L. Scofield	B. F. Bailey
Milwaukee, School of Engineering of, 415 Marshall St., Milwaukee, Wis	G. E. Henkel		J. D. Ball
Minnesota, University of, Minneapolis, Minn	C. L. Elliott		H. Kuhlmann
Mississippi Agricultural & Mechanical College, A. & M. College, Miss	R. S. Kersh		L. L. Patterson
Missouri School of Mines & Metallurgy, Rolla, Mo	H. H. Brittingham	E. J. Gregory	I. H. Lovett
Missouri, University of, Columbia, Mo	C. E. Schooley	W. D. Johnson	M. P. Weinbach
Montana State College, Bozeman, Mont	J. M. Fjeld	G. E. West	J. A. Thaler
Nebraska, University of, Lincoln, Neb	G. W. Cowley	L. T. Anderson	F. W. Norris
Nevada, University of, Reno, Nevada	Alden McCullom		S. G. Palmer
Newark Collegeof Engineering, 367 High St., Newark, New Jersey	C. P. Hurd		
New Hampshire, University of, Durham, N. H	N. J. Pierce	M. W. Cummings	L. W. Hitchcock
New York, College of the City of, 139th St. & Convent Ave., New York, N. Y	Daniel Klatzko	Walter Broleen	Harry Baum
New York University, University Heights, New York, N. Y	G. A. Taylor	A. W. Schneider	
North Carolina State College, Raleigh, N. C	O. M. Carpenter	W. E. Moseley	
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Switches.—Bulletin 21, 8 pp. Describes Wadsworth accessible fuse meter service and main entrance switches. Wadsworth Electric Manufacturing Company, Inc., Covington, Ky.

Resistance Thermometers.—Catalog 80, 28 pp. Describes L & N resistance thermometers for temperature measurements. Leeds & Northrup Company, 4901 Stenton Avenue, Philadelphia.

Megohmer.—Bulletin 170, 8 pp. Describes model "DM" megohmer, a combined megohmmeter and voltmeter with a self-contained direct-current generator. Herman H. Sticht & Company, 15 Park Row, New York.

Superheaters.—Catalog 304, 48 pp. Describes Foster superheaters and consists largely of illustrations of installations. Foster Wheeler Corporation, 165 Broadway, New York.

Synchronous Motors.—Bulletin, 56 pp., entitled "The Most Efficient Drive in Industry." The advantages of the synchronous motor in comparison with other types, the theory of its operation and its development are covered, and the last half of the book is devoted to applications. Electric Machinery Manufacturing Company, Minneapolis.

Steam Turbines.—Bulletin, 132 pp. (in German). This bulletin, entitled "25 Years of A. E. G. Turbines" commemorates the twenty-fifth anniversary of building of steam turbines by the Allgemeinen Elektricitats-Gesellschaft, Dorotheenstrasse 40, Berlin, Germany. The brochure is copiously illustrated detailing the process of manufacture.

Flywheel Effect Recommendations for Air Compressors.—Bulletin 501, 16 pp. entitled "Flywheel Effect Recommendations for Air Compressors Based on Ideal Synchronous Motor Drive." Information is given on how to obtain flywheel effect for any type, horsepower, or speed, being based on a standard motor of 100 horsepower at 200 rev. per min., 60 cycles. The Ideal Electric & Manufacturing Co., Mansfield, Ohio.

Electrical Precipitation.—Bulletin 200, 8 pp., is a brief history of the Cottrell process of electrical precipitation for the recovery of solids or liquids from air or gases. Applications are described. Bulletin 201, 4 pp., on removal of ash and flue dust in powdered fuel plants. Bulletin 202, 4 pp. on detarring manufactured gas. Research Corporation, 25 West 43rd Street, New York.

Laboratory Apparatus.—Catalog, 140 pp. Describes the complete line of General Radio instruments, largely specialized apparatus for measurements at audio and radio frequencies. Many of these instruments are also particularly adapted for use at commercial frequencies and in direct current work. Chapters are devoted to condensers, resistance devices, inductances, bridges, frequency standards, oscillators, meters and transformers. General Radio Company, 30 State Street, Cambridge (39) Mass.

NOTES OF THE INDUSTRY

The Habirshaw Cable & Wire Corporation has removed its offices from 10 East 43rd Street to the Woolworth Building, 233 Broadway, New York.

The Lincoln Electric Company, Cleveland, Ohio, announces the opening of a San Francisco office at 533 Market Street, in charge of W. S. Stewart. A complete line of "Linc-Weld" motors, "Stable-Arc" welders and arc welding supplies is being carried. L. P. Henderson, formerly of the Chicago office, has been transferred and put in charge of the Minneapolis district. Robert Notvest has been transferred from Kansas City to Indianapolis where he will have charge of the Indianapolis district. R. E. Mason has been sent to Kansas City to replace Mr. Notvest. N. L. Nye has been stationed at Akron, Ohio, under the direction of R. P. Tarbell, manager of the Cleveland district.

Westinghouse Purchases Subsidiary Manufacturers.—Announcement has been made that Kaestner & Hecht Company will now be known as Westinghouse Electric Elevator Company and that the headquarters and plant of the new company will be located in Chicago. In 1926, the Westinghouse Company secured a controlling interest in Kaestner & Hecht Company, and considerably extended the scope of the business. District sales offices and service shops are already established in principal cities and more will be opened in the near future The company will operate as a separate unit of the Westinghouse Electric and Manufacturing Company.

High Voltage Transmission in Canada.—The highest transmission voltage in Canada has been started with the opening of the new Quebec section between Paugan Falls and Toronto, with operation at 220,000 volts. Twelve transformers for operation at 220,000 volts were supplied to the Gatineau Power Company by the Canadian General Electric Co., Ltd. Nine of these transformers are rated at 19,000 kv-a., 25 cycles, and step the generator voltage up from 6600 to 220,000 volts. The remaining three are rated at 20,000 kv-a., 25 cycles, and will be used to supply power to a 110,000-volt transmission system from the 220,000-volt line. The generating stations of the Gatineau Power Company are approximately 250 miles from Toronto.

F. R. Fishback, New Vice-President of NEMA.—F. R. Fishback, president of the Electric Controller & Manufacturing Company, Cleveland, has just been elected vice president in charge of the Apparatus Division of the National Electrical Manufacturers Association, according to an announcement from Alfred E. Waller, managing director of the Association. Mr. Fishback was elected to the office of vice president of NEMA at a meeting of the executive committee of the Board of Governors. He replaces N. A. Wolcott, resigned. Mr. Fishback's business experience with the Electric Controller & Manufacturing Company has been on the commercial side. He has held the position of sales manager and in 1924 was appointed vice president and secretary. The following year he was elected president, which position he now holds. As vice president of the Apparatus Division of NEMA, Mr. Fishback will represent a group which includes about 85 per cent of all the manufacturers of electrical apparatus and machinery in the country.

Novel Type Generators for S. C. Power Company.—A contract for the powerhouse generators to be installed in the Saluda River hydro-electric development of the Lexington Water Power Company of South Carolina was recently awarded to the Westinghouse Electric and Manufacturing Company.

The power plant will have an initial installation of 200,000 horsepower and an ultimate capacity of at least 300,000 horsepower. Four turbines will first be installed, each of 50,000 horsepower capacity. They will be connected directly to Westinghouse generators, each of which will have a rating of 40,625 kv-a. at 13,800 volts, and a speed of 138 revolutions per minute. The generators will be built at East Pittsburgh in the near future.

Radically new design features will be found in these generators, such as the elimination of upper guide bearings and the construction of the rotor in the form of an umbrella. The thrust bearing is to be mounted in the lower bracket, under the umbrella formation of the rotor, instead of at the top, as is customary.